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History, Manufacture and Analysis of Maple Products.

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(*Continued from vol. clxvi, p. 280.*)

SPECIFIC GRAVITY. DENSITY.

The standard density of maple sirup is 1.325 or 36° Baumé; this corresponds to a sirup, a gallon of which will weigh eleven pounds, and which has a boiling point of 103.9 °C. (219°F.). Sirups are found which are thinner and others thicker than this. Some analysts use an ordinary sp. gr. hydrometer for taking density, the writer prefers a picnometer bottle with a thermometer stopper. The use of a picnometer requires careful manipulation and will then give more accurate results than any other apparatus. The writer proceeds as follows: The sirup is carefully poured into a small, lipped Erlenmeyer flask and cooled under the tap or in ice water until it is about 1° colder than the temperature at which sp. gr. is to be taken (15.5°C.); the sirup is then poured carefully into the picnometer (the 25 c.c. size) which is also

cooled to about 15.5°; the thermometer is then inserted, the whole washed and wiped and the cap put on when thermometer shows 15.5°C.. Care must be taken not to agitate the sirup at any time since it becomes filled with small bubbles which separate only very slowly. Some analysts cool the sirup to 10 or 12° and place it in picnometer, insert the thermometer and wait until the latter shows 15.5°. This will not give accurate results, since the picnometer and outer layer of sirup are considerably warmer than 15.5° when the thermometer shows this temperature. The specific gravity may be used for estimating "total solids" by using the table* prepared for this purpose. Specific gravity multiplied by 8.32 gives the weight of a gallon of sirup. Hortvet found the average sp. gr. of twenty-two samples of pure maple sirup to be 1.3166, corresponding to a weight of 10.95 pounds per gallon.

TOTAL SOLIDS. MOISTURE.

Total solids may be determined directly or indirectly. The direct determination consists in drying the sample (about three grams) in a flat-bottomed dish, at temperature of boiling water. Hortvet† dries for eight hours, or to constant weight. This direct method has the objection of all methods where sugar or saccharine substances are dried at 100°; the sugars undergo chemical changes during the long period of drying necessary to expel all water; the long time, and repeated weighings required make the process tedious.

The writer much prefers to use the indirect method, in which the solids are estimated from the density, using a table. For sirups, the method of obtaining density has been described under "Specific Gravity:" For sugars, a weighed amount, about 25 g., is placed in a 100 c.c. flask, dissolved and made up with water to mark and specific gravity of this solution taken. The total soluble solids can then be calculated from the following formula:

$$\text{Soluble solids} = \frac{100 \times \text{sp. gr.} \times \% \text{ solids corresponds to sp. gr.}}{\text{weight taken.}}$$

*Bul. 107, Bureau of Chem. U. S. Dept. Agr., p. 66.

†Jour. Am. Chem. Soc., 26, p. 1527.

The amount of total solids in a maple product, taken by itself, has no significance, except that it shows how thick or thin a sirup is, or how much water there is in a sugar. Hortvet found an average of 66.45% of total solids in twenty-two samples of pure maple sirup, using the direct drying method. For nineteen samples of pure sugar the average was 90.70% total solids. The relation of total solids to sucrose will be discussed later,

PROTEIN.

The protein (nitrogen) determination is usually not made in an analysis of a maple product. Since, however, all pure products have a certain percentage of protein, the addition of adulterants containing little or no protein (glucose, cane sugar) causes a corresponding lowering of this percentage. Hortvet* found that pure sirups contain from 0.223 to 0.334% protein, while in sugar he found from 0.32 to 0.816%. Wiley† found an average of 0.0143% protein in the sap of 1500 trees; since in making sirup from a 3% sap, it must be concentrated about twenty-two times, the protein would become 0.227% in the resulting sirup. Wiley also found some trees producing sap containing 0.0242% protein; this would produce a sirup containing 0.532% protein. Some protein is lost during evaporation, since it coagulates and is removed by skimming.

The protein is determined by the Gunning nitrogen process, using about five grams of sirup or sugar. The per cent. of nitrogen found, multiplied by 6.25 gives the protein.

MALIC ACID.

One of the most important non-sugar constituents of maple sap is malic acid. It is always present in genuine maple products. It exists, as was pointed out under "Physiology," partly as free

*Jour. Am. Ch. Soc., 1904, p. 1539.
†Bul. 5, Div. of Chem. Dept. Agr., p. 210.

but mainly as combined malic acid,* as calcium, potassium and sodium malates.† The amount of total malic acid in a maple product varies considerably; one cause is that trees in different localities produce sap with different amounts of malic acid; the main cause, however, lies in the fact that as the sap is concentrated, the malic acid is separated as the calcium salt ("niter") and is more or less completely removed, part of course remaining in solution in the sirup. Jones‡ reports for sirups an average of 0.53% with 0.41% and 0.72% as minimum and maximum (thirty-five samples); for sugars the average is 0.75%, minimum 0.65%, maximum 0.84%. Hortvet§ using the same method of analysis obtained considerably higher results; sirups, averaging 1.08%, minimum 0.84%. maximum 1.28% (seventeen samples) for sugars: average 1.28%, minimum 0.98%, maximum 1.67%.

Since both analysts used the same method, this difference in results can be explained partly by a difference in the products analyzed; Jones' analyses were on Vermont products, while Hortvet analyzed mostly Minnesota, New York, Pennsylvania and Ohio products. Another cause for difference in results lies in difference in manipulation of the same method, *i. e.*, by different analysts. Hortvet,¶ as associate referee on saccharine products for the Association of Off. Agr. Chemists, reports malic acid in two maple sirups and two sugars, the results being obtained by seven different chemists, all using the same method:**

	Average.	Minimum.	Maximum.
No. 1, Ohio sirup.....	0.63%	0.30%	0.93%
No. 2, Vermont sirup.....	0.76	0.31	1.26
No. 3, Vermont sugar.....	0.93	0.61	1.21
No. 4, Vermont sugar.	0.94	0.71	1.23

These differences are enormous and proved that the method used is unreliable.†† Jones,‡‡ who was associate referee the fol-

*Free and combined malic acid are found in some plants, notably in Rhûs glabra, smooth sumac.

†Jones, 18th An. Report Ver. Station, p. 316.

‡Ibid, p. 317.

§Jour. Am. Chem. Soc., 1904, p. 1528.

¶Proceed. 22d An. Con. A. O. A. C., 1905, p. 42.

**Cir. 23, Bur. Chem.

††The disturbing factor was NH_4OH; the precipitation is made from an ammoriacal solution.

‡‡Proceed. 23d An. Con. of A. O. A. C., 1906, p. 14.

lowing year, took up this same subject. Three samples of sugar were sent out to different chemists, thirteen of whom reported results:

	Average.	Minimum.	Maximum.
No. 1—40% maple + 60% cane sugar.....	0.08%	0.03%	0.13%
No. 2—40% maple + 60% lt. brown sugar...	0.08	0.04	0.13
No. 3—Pure maple sugar.....	0.39	0.22	0.64

The writer's results on the above samples were 0.03%, 0.05%, and 0.29%, respectively.

These results are still far from satisfactory and the method could not be used for the determination of actual amounts of malic acid. As will be seen from these figures, the method can however, be used for differentiating between pure and adulterated samples. (Several of the analysts reported results by this method, using ammonia, *i. e.*, precipitating from an ammonical solution; in each case this gave much higher results.) The method as used and reported on was to precipitate the malic acid with $CaCl_2$ (10% sol.), from neutral solution, add alcohol, let stand, filter, wash with alcohol, dry, ignite, titrate $CaCO_3$, using methyl orange.

The method for determining the malic acid value of maple products adopted provisionally by the Official Association of Agricultural Chemists* is as follows: Weigh 6.7 grams of the sample into a 200 c.c. beaker and add water to make a volume of 20 c.c.. Make the solution slightly alkaline with ammonium hydroxide, add 1 c.c. of a 10% solution of calcium chlorid, then add 60 c.c. of 95% alcohol. Cover the beaker with a watch glass, heat for one-half hour on a water bath, then turn off the flame and allow the beaker to stand over night. Filter through good quality filter paper, wash the precipitate with hot 75% alcohol until free from chlorids, then dry and ignite. Add from 15 to 20 c.c. of tenth-normal hydrochloric acid to the ignited residue, thoroughly dissolve the lime by heating carefully to just below boiling, cool and titrate the excess of HCl with tenth-normal Na OH, using methyl orange. One-tenth of the number of cubic centimeter of acid neutralized by the ignited residue expresses the malic acid value.

*Bul. 107, Bur Chem., U. S. Dept. Agr., p. 73.

ASH.

The work of Jones* on the ash of maple products was a valuable addition to the methods now in use for detecting adulteration. Maple products are never more than partially refined; if they were refined to the same extent as cane sugar is, then they would lose the flavor—maple flavor— to which they owe their value. Since glucose was readily detected by the polariscope, the "mixers" soon abandoned it and used cane sugar for adulterating maple products; here the polariscope is of no help, and until Jones' work on the ash and the work of others on "lead precipitate" became known, it was considered imposisble for a chemist to detect the adulteration. Cane sugar has practically no ash and its addition to maple products decreases the percentage of ash correspondingly. Commercial brown sugar sometimes contains about the same amount of ash as maple products, so that, if simply the percentage of ash were determined, the adulteration would not be detected. But brown sugar ash differs from maple ash in character, especially in its ratio of soluble to insoluble ash; an average of forty-eight results reported by Jones† gives total ash as 0.60%; soluble ash, 0.38% insoluble ash, 0.22%; brown sugars having about 1.00% of ash have only 0.10% insoluble ash.

Variations in the percentage of ash in maple products are due to a difference in soil where the trees grow, but mainly to a difference in manufacture. The amount of ash depends a great deal upon the amount of "niter" left in the sample; if a sugar is made by simply evaporating sap, without clarifying in any way, then the ash will be high. Since sugars are usually more or less incompletely clarified or filtered—sometimes not at all—it follows that the greatest variations as well as the highest percentages are to be expected in these. This the writer found to be the case, as will be seen from analyses reported. There is much less variation in ash percentage in clarified sirup. In order to obtain a better indication of purity of a maple product from its ash content, Jones‡ proposes to prepare all samples for analysis by subjecting them to a clarification in the laboratory. This he does by dis-

*17th An. Rpt. Ver. Station, p. 446; also, 18th An. Rpt., p. 315.
†18th An. Report, Ver. Station, p. 317.
‡18th An. Report, Ver. Station, p. 327.

solving 4 grams of sirup or sugar in 5 to 10 c.c. hot water for sirups, 15 to 20 c.c. for sugars; boil carefully on an asbestos board, stir and boil until an accurate and delicate thermometer indicates 219°F. for a good or medium grade and 220°F. for a poorer grade of product. The sirup is then filtered hot through a dry, double S. & S. 597 filter without suction; pure maple usually filters quite readily. This brings all samples on a common basis of concentration and clarification and reduces the variations in percentage of ash (also malic acid and "lead precipitate") to a minimum. As is to be expected, this affects sugars more than sirups. Jones* found the following percentages of ash in sirups and sugars:

	Total ash.	Soluble ash.	Insoluble ash.
Average in original sirups	0.63	0.38	0.25
Average in filtered sirups	0.58	0.36	0.22
Average in original sugars	0.94	0.45	0.49
Average in filtered sugars	0.55	0.36	0.19

These results also show that there is a close agreement in the results of the filtered sirups and sugars.

As an average of forty-eight analyses of pure maple sirups Jones† found the following, the maximum and minimum being given also:

Sirups:	Total ash.	Soluble ash.	Insoluble ash.
Average	0.60	0.38	0.22
Maximum	0.86	0.47	0.51
Minimum	0.50	0.29	0.16

For forty-two *sugars* he found the following:

Average	0.91	0.48	0.43
Maximum	1.32	0.63	0.87
Minimum	0.64	0.36	0.20

Hortvet‡ found the following in pure products:

Sirups:			
Average	0.68	0.39	0.31
Maximum	1.01	0.49	0.55
Minimum	0.52	0.21	0.15

*Ibid, p. 320.
†18th An. Ver. Report, p. 317.
‡Jour. Am. Chem. Soc., 26, p. 1528.

Sugars:			
Average	0.91	0.45	0.51
Maximum	1.30	0.67	0.78
Minimum	0.65	0.33	0.32

The results of the cooperative analyses by thirteen chemists on the same sample of pure sugar are as follows:*

Sugars:			
Average	0.73	0.44	0.29
Maximum	0.86	0.59	0.34
Minimum	0.61	0.32	0.22
Sy	0.74	0.46	0.28

Woodman† obtained the following percentages of ash in pure maple products:

Sirups:	Total ash.	Soluble ash.	Insoluble ash.
Average	0.62	0.38	0.24
Sugars:			
Average	1.02	0.52	0.50

Analyses by the writer of maple products known to be pure are as follows:

Sugars:

Sample No.	Total ash	Soluble ash.	Insoluble ash.
1	0.81%	0.42%	0.39%
2	0.71	0.58	0.13
3	1.22	0.70	0.52
4	0.71	0.44	0.27
5	0.62	0.40	0.22
6	0.63	0.45	0.18
7	0.79	0.57	0.22
8	0.90	0.47	0.43
9	0.82	0.42	0.40
10	0.73	0.55	0.18
Average	0.79	0.50	0.29

Sirups:

Sample No.	Total ash.	Soluble ash.	Insoluble ash.
15	0.48	0.32	0.16
16	0.76	0.45	0.31
17	0.64	0.38	0.26
18	0.47	0.34	0.13
22	0.50	0.29	0.21

*Proceed. 23d An. Convention, U. O. A. C., p. 17.

†Technological Quarterly, 18, p. 150.

24	0.42	0.26	0.16
26	0.70	0.37	0.33
27	0.71	0.33	0.38
28	0.68	0.41	0.27
31	0.50	0.35	0.15
33	0.40	0.32	0.08
36	0.61	0.38	0.23
39	0.55	0.32	0.23
40	0.65	0.41	0.24
49	0.54	0.35	0.19
50	0.72	0.41	0.31
Average	0.58	0.35	0.23

In addition to the quantities of soluble and insoluble ash, the character of the ash is also a valuable indication. This applies especially to the alkalinity of the soluble and insoluble ash. Jones reports * the following figures for pure products; the results being expressed as cubic centimeters of tenth-normal HCl required to neutralize the ash from one gram of sample, using methyl orange indicator:

	Alkalin. Sol. ash.	Alkalin. Insol. ash.
Sirups (48).		
Average	0.51%	0.54%
Maximum	0.66	0.94
Minimum	0.30	0.36
Sugars (43).		
Average	0.61	0.91
Maximum	0.80	1.72
Minimum	0.40	0.55

The pure sugar analyzed by thirteen chemists in the cooperative work to which reference has previously been made gave these results:

	Alkalin. Solvent ash.	Alkalin. Insolvent ash.
Average	0.53%	0.70%
Maximum	0.66	0.88
Minimum	0.36	0.60
Sy	0.60	0.60

Hortvet† found the following:

Sirups (13).		
Average	0.52	0.61
Maximum	0.66	0.85
Minimum	0.38	0.31

*18th An. Report Ver. Sta., p. 317-318.

†Jour. Am. Chem. Soc., 26, p. 1528.

Sugars (11).		
Average	0.66	1.06
Maximum	0.95	1.46
Minimum	0.55	0.66

The writer found the following alkalinities in the ash from pure products:

Sugars:

Sample No.	Alkalin. Soluble ash.	Alkalin. Insoluble ash
1	0.59c. c.	0.20c. c.
2	0.64	0.42
3	0.90	0.81
4	0.61	0.68
5	0.53	0.68
6	0.57	0.74
7	0.69	0.74
8	0.64	0.93
9	0.61	0.82
10	0.57	0.53
Average	0.64	0.66

Sirups:

Sample No.	Alkalin. Soluble ash.	Alkalin. Insoluble ash.
15	0.19	0.39
16	0.42	0.46
17	0.38	0.38
18	0.17	0.39
22	0.24	0.40
24	0.17	0.39
26	0.15	0.74
27	0.24	0.72
28	0.28	0.64
31	0.17	0.41
33	0.20	0.33
36	0.21	0.46
39	0.18	0.56
40	0.22	0.46
49	0.08	0.45
50	0.36	0.46
Average	0.23	0.48

Hortvet reports* the following analyses of ash of pure maple products:

*Jour. Am. Chem. Soc., 26, p. 1541.

	Silica and Sand	CO_2	CaO	MgO	Mn_3O_4	K_2O	Na_2O	SO_3	P_2O_5	Cl
Minnesota Sirup...	2.25	30.86	18.60	4.65	0.75	31 58	6.86	2.31	1.64	.09
Penn Sirup.....	2.17	28.70	20.35	4.16	2.22	30.87	4.01	2.42	4.67	.....
Vir. Sugar.....	9.77	30.22	23.05	2.54	0.45	28.37	2.84	1.15	1.18	trace
Vir. Sugar	4.48	30.79	20.62	3.75	0.50	33.06	3.56	1.77	1 24	trace

In most cases the ash of a pure maple product has a distinct green color, sometimes very faint and sometimes an intense green: in some instances the writer has found no green color in ash of pure products. This color is best observed after fusing the ash. Hortvet reports* green colored ash for Minnesota maple products as an almost constant indication. The writer has analyzed a number of pure New York State products that showed no green ash; some of these developed the green color after fusing. Jones† reports the presence of manganese in maple ash, but does not mention or discuss the green colored ash. As will be seen from the ash analyses above mentioned, manganese is present in quite considerable quantities, not merely as traces.

Directions for determination of manganese are given in Circular 23, Bur. of Chemistry, Department of Agriculture, p. 6. The writer found 0.55% of manganese (as Mn_3O_4) in the ash of a pure maple sugar, the ash of which was 0.81% and quite green in color. This green color is no doubt due to the changing of the manganese into manganates; the potassium and sodium, and the calcium salts of the organic acids on ignition of the sample are converted into the corresponding carbonates, and the latter react with the manganese on fusion, and manganates are produced. On dissolving a number of green ashes in HCl, the writer observed a change in color to a permanganate pink, indicating a change from manganates to permanganates.

Organic salts of manganese, on ignition, are converted into MnO mostly; when this oxid is heated in the air with sodium or potassium carbonate or hydroxid, oxygen is absorbed and sodium or potassium manganates are formed as follows:

$$MnO + Na_2CO_3 + O_2 = Na_2MnO_4 + CO_2.$$
$$MnO + K_2CO_3 + O_2 = K_2MnO_4 + CO_2.$$

*Ibid.

†17th An. Report Ver. Station, p. 456.

With hydroxid, the reaction is as follows:

$$MnO + 2\,KOH + O_2 = K_2\,MnO_4 + H_2O.$$

The alkali manganates are intensely green in color, quite soluble in water, but are decomposed by excess of water or by acids, forming permanganates with a characteristic red or pink color; MnO_2 (brown, insoluble) is also formed:

$$3\,K_2\,MnO_4 + 2\,H_2O = 2\,K\,MnO_2 + MnO_2 + 4\,KOH.$$

The solubilities and color changes the writer has repeatedly observed in the ash from pure maple products.

It has been supposed that probably all or at least most of the manganese found in maple ash is derived from the vessels used in collecting and evaporating the sap. To get information on this point, the writer evaporated and ashed several samples of sap that had never been in contact with anything except a jug and a platinum dish; the ashes showed a typical green maple-ash color.

As before stated, the ash of pure maple products is not always green. The writer has analyzed a number of pure samples that gave no green ash. This was the case mostly in old sirups, and it is quite probable that the manganese compounds were removed when the sirups were made, especially those made from maple sugar by dissolving and filtering the latter. No doubt some soils contain so little manganese that not enough would find its way into the sap to produce a green ash. This is indicated by the fact that samples from certain districts produce a much greener ash than others.

Maple products are the only saccharine substances with a manganese content sufficiently high to produce a green ash, and a green ash is an indication of at least some maple product in the sample. The writer has repeatedly observed a green ash in black peppers; this appears to be due also to manganese.* König† reports a green ash from Rio coffee.

The writer makes the following ash determinations on maple products.

1. Total ash, as % on original sample.
2. Soluble ash as % on original sample.

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*The writer expects to determine percentage of Mn in several samples of pepper now on hand.

†Untersuchung, Nahrungs ú. Genussmittel, I, p. 987.

3. Insoluble ash, as % on original sample.
4. Alkalinity of soluble ash, expressed in "number of c.c. of tenth-normal acid necessary to neutralize ash from one gram of original sample (methyl orange)."
5. Alkalinity of insoluble ash, as above.

1. *Total ash:*

Weigh ten grams of sample in a tared flat-bottomed platinum dish, heat on asbestos gauze with bunsen burner; when charred, transfer to a muffle furnace and heat until ash is white or until the residue no longer glows—do not fuse after ash is white. Cool and weigh.

2. *Soluble ash:*

Total ash minus insoluble ash.

3. *Insoluble ash:*

Add water to residue from "total ash," heat nearly to boiling, filter (ash free filter), wash with hot water till filtrate equals about 60 c.c. Return filter paper and residue to platinum dish, dry, ignite and weigh.

4. *Alkalinity of soluble ash:*

Allow filtrate from "insoluble ash" to cool, add methyl orange and titrate with tenth-normal acid.

5. *Alkalinity of insoluble ash:*

The insoluble ash is treated with an excess (15 c.c.) of tenth-normal acid (HCl), heat to boiling point on asbestos gauze, cool, add methyl orange, and titrate excess of acid with tenth-normal alkali. (NaOH).

When igniting pure maple products for "total ash" the writer observed that there was always considerably more frothing and tendency to boil over than in adulterated samples, some of the latter showing scarcely any frothing or bubbling. This led the writer to make further experiments, and resulted in the "foam test," to be described later.

SUGARS

Under this heading there will be considered the various saccharine matters that may be present in a pure or adulterated product.

Sucrose (cane sugar) $C_{12}H_{22}O_{11}$.

As was stated in connection with the physiology of maple sap,

the principal sugar contained in it is sucrose, which is chemically identical with cane sugar. A determination of sucrose alone would not detect adulteration of a maple product with cane sugar. The amount of sucrose in maple products varies according to the method of manufacture used,—the degree of concentration and extent of inversion of sucrose. Hortvet* reports the following:

	Sucrose.	Total solids	Difference.
Sirups (22) average.....	60.90	66.45	5.55
Sugars (19) average..... ...	84.77	90.70	5.93

Sirups reported in New Hampshire Station Bulletin 25 are as follows:

	Sucrose.	Total solids	Difference.
Sirups (8) average.....	64.77	68.00	3.23

These, however, were freshly and carefully prepared and contain only about (average) .20% reducing sugar; this leaves a difference of 3.03% solids not sugar. Hortvet's sirups contained (average) 2.83% reducing sugar, leaving 2.72% solids not sugar.

The writer's results on pure products are as follows:

	Sucrose.	Total solids	Difference.
Sirups (16) average.....	61.39	67.05	5.66
Sugars (10) average.....	88.87	96.65	7.78

These data show a difference of 5.66% for sirups and 7.78% for sugars between the total solids and the sucrose; this difference is made up of invert or reducing sugar and "solids not sugar." It follows that in a pure maple product there is always this considerable difference and is not found in cane sugar or products adulterated with cane sugar, decreasing in the latter as the amount of cane sugar added increases. To be sure the presence of glucose increases this difference, but this adulteration is readily detected, as will be seen later.

Invert sugar, (reducing sugar) sometimes erroneously called "glucose." This is present in the sap before evaporation, and the amount increases, relatively, as the sap is evaporated, the sucrose being inverted by the heat in the presence of the salts in the sap; further inversion may be caused later by enzyms and micro-organ-

*Jour. Am. Chem. Soc., 26, p. 1528.

isms*. As the sap season advances the amount of invert sugar increases. Invert sugar is a mixture of equal quantities of dextrose and levulose, one molecule of sucrose, $C_{12}H_{22}O_{11}$, on inversion forming two molecules of $C_6H_{12}O_6$. In many analytical reports this invert sugar is given as "reducing sugar," since it reduces Fehling's solution while sucrose does not. The amount of reducing or invert sugar in maple products varies considerably, from less than one per cent. to more than ten per cent. have been found. Hortvet† found the following percentages of invert sugar:

	Average.	Maximum.	Minimum.
Sirups (22)	2.83	9.17	0.60
Sugars (19)	3.27	8.37	1.16

The writer's results are as follows:

Sirups (13)	2.71	4.20	1.34
Sugars (9)	3.27	8.05	1.14

Sample No. 3, a very dark, almost black, sugar, gave 14.14% reducing sugar and is not included in the above.

Sometimes analysts, especially those who analyze maple products only occasionally, fall into the error of reporting reducing sugar as glucose; in fact, unles polariscope readings are also used, especially at 87°C. after inversion, it would in most cases be impossible for the "occasional" analyst to differentiate between invert sugar and added glucose. On the other hand, although it is true that a pure maple product always contains reducing sugar, its presence must not be interpreted to mean that the product is pure, since added cane-sugar syrup on boiling also produces invert sugar. Again, the entire absence of, or only traces of invert sugar indicates that the product is not pure maple.

To study the effect of heat on a maple sirup, Hortvet‡ boiled a sample for forty-five hours, making analyses at five hours' intervals. The loss in "total sugar" between the sixth and seventh periods was caused by fermentation, three months having elapsed between these periods.

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*According to Geerlings (Chem. Centbl., 1898, p. 711) cane sugar in the presence of glucose is inverted by neutral salts; all mono saccharids can cause this inversion. This may account for the high invert sugar found in samples adulterated with glucose.

†Jour. Am. Chem. Soc., 26, p. 1528.

‡Jour. Am. Chem. Soc., 26, p. 1539.

Time Hours	Polarization		Sucrose %	Reducing Sugar %	Total Sugar %	Sucrose in Total Sugar %	Reducing Sugar in Total Sugar %
	Direct	Invert.					
	original	sample	40.33	1.67	42.00	96.01	3.99
5	+ 38.0	— 14.5	39.47	2.35	41.82	94.31	5.69
1	+ 36 0	— 13.6	37.15	3.60	40.75	91.16	8.84
15	+ 34.0	— 12.2	34.73	6.04	40.77	85.18	14.82
20	+ 26.9	— 11.8	29.10	11.12	40.32	74.07	25.93
25	+ 20.2	— 11.2	23.43	17.09	40.52	57.82	42.18
30	+ 14.0	— 11.2	18.82	21.44	40.26	46.77	53.23
35	+ 7.5	— 11.2	10.76	26 75	37.51	28.69	71.31
40	— 4.5	— 13.1	6.57	30.89	37.46	17.54	82.46
45	— 9.0	— 10.2	0 28	37.25	37.53	0 78	99 22

Invert sugar and glucose both reduce Fehling's solution, but can be differentiated by means of a polariscope; invert sugar at 87°C. gives a 0 reading on the Soliel-Ventzke sugar scale, while glucose, which is largely dextrose, gives a *plus* reading according to the amount present. Although invert sugar consists of equal amounts of a right and a left rotating sugar, yet at ordinary temperatures the effect of the levulose is much greater than that of the dextrose, and the reading is *minus;* at 87°C. they have equal rotating power and the reading is 0.

GLUCOSE.

This is not a normal constituent of maple products; it is considered here because it is still occasionally used as an adulterant, however, not nearly as much as formerly, since it can readily be detected. Since both glucose and invert sugar reduce Fehling's solution, care must be exercised not to confound these two when only chemical methods of analysis are employed. According to Leach* the grade of glucose usually used for adulterating purposes is the 42° Bé variety; this polarizes at about 175° (max.). Since, in a maple product after inversion, both the original invert sugar and that produced from the sucrose read 0° at 87°C., the presence of glucose is indicated by a *plus* reading.

*"Food Inspection and Analysis," p. 505.

ANALYTICAL METHODS FOR SUGARS.

There are two classes of methods for the determination of sugars, chemical and polariscopic.

SUCROSE, (a) *Chemical Method:** Determine the reducing sugars with Fehling's solution (copper oxide method) and calculate to "invert sugar," using the tables given in Bulletin 107. Then determine reducing sugar after inverting sample and calculate this also to invert sugar. Subtract invert sugar before inversion from that after inversion; the difference is invert sugar formed from sucrose; this difference multiplied by 0.95 gives sucrose. The writer prefers the Reduction method and tables given by Munsen and Walker.†

(b) *Polariscope Method.*

A normal weight (26.048) of the sample is dissolved in water, clarified with subacetate of lead, diluted to 100 c.c. and filtered. The filtrate is polarized at 20°C. in a 200 m.m. tube; this gives "direct" reading, or reading "before inversion." For inversion take about 60 c.c. of the filtrate, add enough anhydrous $Na_2CO_3 + Na_2SO_4$ (1.10) to remove excess of subacetate of lead, and filter; of the clear filtrate take 50 c.c., place in a 100 c.c. flask, add 25 c.c. water, 5 c.c. HCl (38.8%); mix thoroughly and place in water bath of 70°C. so that the solution reaches 69°C. in about two and a-half to three minutes; keep at 69°C. for seven to seven and a-half minutes; remove, cool rapidly to 20°C. and dilute to 100 c.c.; polarize at 20°C. in a 200 m.m. tube; this multiplied by two gives "invert" reading or "reading after inversion." From the direct and invert readings, the sucrose is calculated as follows:

$$\text{Sucrose} = \frac{100\ (\text{direct} + \text{invert})}{142.66\ \dfrac{\text{temperature}}{2}}$$

INVERT SUGAR. This is determined by chemical methods; the writer uses Munsen and Walker's method. For ordinary maple products the preparation of the sample is made as follows: Weigh 25 g. into a 100 c.c. flask, add water to about 75 c.c.; add

*Bul. 107, Bur. Chem., Dept. Agr., p. 44.
†Jour. Am. Chem. Soc., 28, p. 663.
Bul. 107, p. 40.

2 c.c. lead subacetate and make up to 100 c.c.; filter, remove excess of lead in solution with adhydrons $Na_2CO_3 + Na_2SO_4$ (1:10) and filter; of this filtrate take 20 c.c. and add to a mixture of 25 c.c. Fehling's solution, No. 1, and 25 c.c. Fehling's solution, No. 2, and 30 c.c. of water; heat this in a 400 c.c. beaker on an asbestos gauze so that this mixture begins to boil in four minutes; continue boiling exactly two minutes, keeping the beaker covered with a watch glass; filter the cuprous oxid at once in a tared Gooch packed with asbestos, using suction; wash thoroughly with water at 60°C., then with 10 c.c. alcohol and 10 c.c. ether; dry for thirty minutes in water oven at 100°C., cool and weigh as cuprous oxid. From the tables find the corresponding amount of sugar. In case of high invert sugar, less than 20 c.c. of the solution must be taken; the amount of invert sugar in the amount taken should not exceed 250 m.g.

GLUCOSE, (a) *Chemical Methods.* These are usually only qualitative, and in most cases unsatisfactory.

(b) *Polariscopic Method.* A high direct reading is an indication of the presence of glucose, since the reading for a normal weight of 42° Bé glucose is about 175° (max.). When glucose is present, the invert reading is usually *plus*. The best quantitative indication is obtained making a reading at 87°C. on the solution prepared for "invert reading," as above described. This reading at 87° is done in a 200 m.m. all-metal, inside gold plated, jacketed tube; hot water is passed through the jacket until the thermometer in the solution to be polarized shows 87°C., at which temperature the reading is made. Since there is no satisfactory form of apparatus on the market for this purpose, and as the writer had to make a great many readings at 87°, the following arrangement (here described for the first time) was used, shown in Plate 15: A form of instantaneous water heater shown in the plate (made by the Buffalo Dental Mfg. Co.) was connected with the polariscope tube, PT in position; HC contains the heating coil; G is the gas supply for the large burner under the coil; CW is the cold water supply, HW is the hot water tube; WW is the overflow from the tube; T the thermometer which passes into the solution to be polarized. GWV shows a combination valve for turning on both water and gas at the same time; at P there is a pilot light. The valves at G and at CW are so regulated that the water passing into the polariscope tube will heat its contents

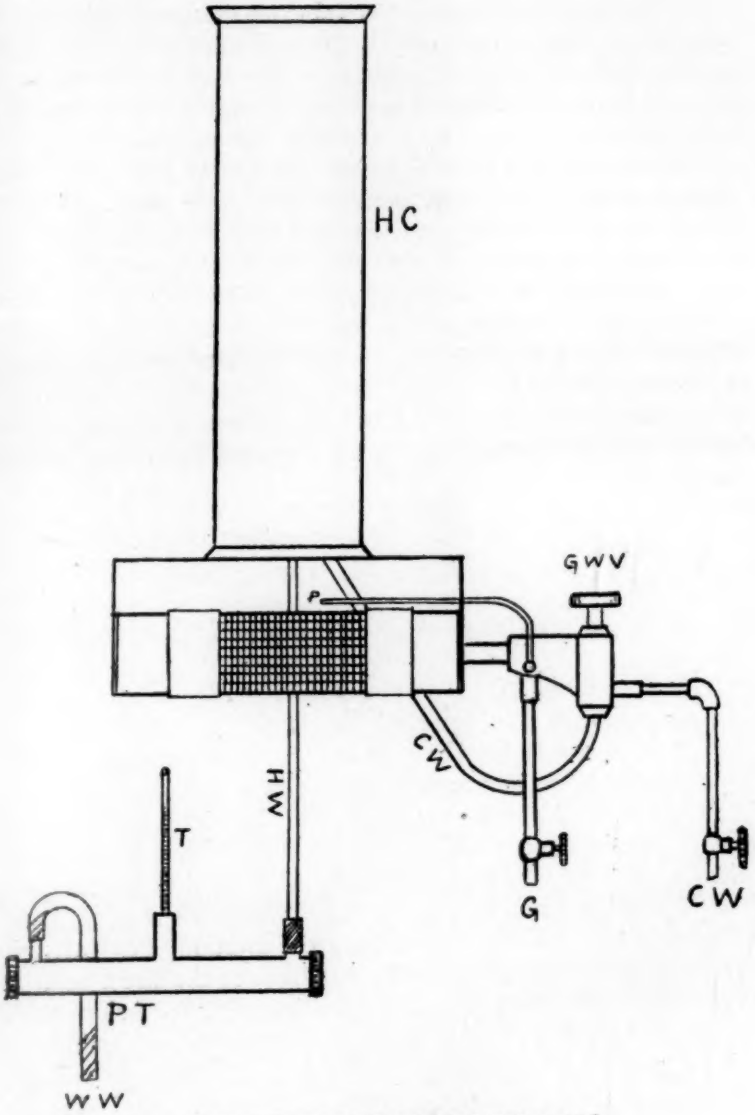


Plate 15. Arrangement for polariscopic readings at 87° C.

to 87°C; when the water supply is cold, in winter, the adjusting of gas and water requires considerable care and experience; it was found necessary to add a second valve on the gas supply pipe G, this second valve being used to shut off most of the gas when starting successive heatings, since the hot water left in the heater from a previous heating is sometimes converted into steam when the full amount of gas is turned on with the valve at GWV.

This arrangement gave excellent satisfaction, both when single readings as well as a large number were to be made. The old arrangement of heating water in a tank by means of a burner and siphoning or allowing it to flow into the polariscope tube is very slow, and often has to be interrupted in the middle of a reading.

When glucose is present in a maple product the direct reading will be higher than the sucrose (clerget) according to the amount of glucose. Leach found 175° as the maximum polarization of a normal weight of commercial 42° Bé glucose, and uses the following formula for getting the approximate percentage of glucose present:

$$\text{Glucose} = \frac{(\text{direct reading.} - \text{Sucrose (clerget)}\ 100}{175}$$

This gives the percentage of glucose expressed in terms of 175° glucose.

It has been shown that a normal (polariscopic) solution of glucose gives a lower reading at 87° than at 20°; also that after inversion, glucose is very hard to read at 87°, since it changes rapidly. This must be taken into account when sirups or sugars containing large amounts of glucose are analyzed. Leach* proceeds as follows: Obtain direct reading as usual. For invert reading start with a separate half-normal weight, invert, neutralize with NaOH, clarify, make to 100 c.c, filter, and make reading at 20° and also at 87°. Since a normal glucose solution at 87° after inversion and neutralization reads about 93% of the direct polarization at ordinary temperature, the reading after inversion and at 87° must be multiplied by 0.93 to get the true reading; multiplying this by 100 and dividing by 163 ($175 \times 0.93 = 162.7$) will give the percentage of glucose, expressed in terms of "175° glucose."

*"Food Inspection and Analysis," p. 514.

Formula:

$$\text{Per cent of } 175^\circ \text{ Glucose} = \frac{(\text{Read, at } 87)\ 93.}{163}$$

LEAD SUBACETATE PRECIPITATE

The addition to maple products of lead subacetate and a qualitative and quantitative study of the resulting precipitate constitutes the most important test to-day in use. Results by this method began to be published about five years ago; the more important modifications will be discussed in the following: Lead subacetate when added to a maple product will precipitate the malic and other organic acids and their salts as well as sulfates, chlorids, carbonates, coloring and other organic matter. That a large proportion is other than malic acid is shown by the fact that on heating this precipitate it does not melt, while lead malate melts quite readily. The quantitative methods used determine one of the following:

(1) The bulk or volume of the precipitate.
(2) The weight of the precipitate.
(3) The amount of lead in the precipitate.
(4) The amount of malic and other acids combined with the lead.

JONES' METHOD*

In this method the volume of the precipitate is measured. The process is as follows: Five grams of sirup or sugar are weighed into a Purdy sediment tube and dissolved in 10 c.c. of water. Two c.c. of official† subacetate of lead are added, mixed, and the tube whirled in a Babcock machine for four minutes at a speed of 1400 revolutions per minute. The volume of the precipitate is then read on the scale. This will be from 1.5 to 3 c.c. for pure maple products. Cane sugar gives but a trace of precipitate while adulterated maple products usually give from 0.1 to 1.0 c.c. This

*17th An. Report Ver. Station, p. 454.
†Bul. 107, Bur. Chem. Dept. Agr., p. 40.

method, the author says, has its limitations, and was designed more especially as a factory test.

HORTVET'S METHOD.*

Working independently of Jones, Hortvet devised the following method, similar to that of Jones, the volume of the lead precipitate being measured. Hortvet devised his method after noticing the wide variation in the volumes of the precipitates formed when clarifying maple products with lead subacetate for making polariscope readings. The apparatus used is shown in Plate 16, the glass tube used having the appearance of an inverted Babcock milk test bottle. For making the test, 5 c.c. of sirup or 5 grams of sugar are put into the tube, 10 c.c. water added, mixed; now add 0.5 c.c. cream of alumina and 1.5 c.c. lead subacetate (official) shake and let stand about one hour. The tube is then placed in the centrifugal and run six minutes; if any material has not settled into the stem of the tube, it is loosened with a fine wire; the tube is whirled another six minutes. Make a blank determination, using water and the reagents; the reading of the blank subtracted from that of the sample gives volume of precipitate. In sirups, this should be divided by the specific gravity of the sample to reduce the reading to a five-gram basis.

The volume of the precipitate will vary the amount of whirling and will depend upon the radius of the centrifugal speed and time. Hortvet used a machine having a radius of 18.5 c.m. and ran it at a speed of 1600 revolutions per minute. In order to secure uniformity of results it is necessary that the same amount of force be used to produce the volume of the precipitate. The formula for centrifugal force is $\text{Force} = \frac{\text{mass} \times (\text{velocity})^2}{\text{radius}}$; calling mass equal to unity and solving for velocity we get

$$\textit{velocity} = \sqrt{\text{Force} \times \text{radius}}.$$

From this formula a numerical expression for "Force" can be computed, then having measured the "radius" for a given machine, the value of "velocity" and the required number of revolutions

*Jour. Am. Chem. Soc., 26, p. 1532.

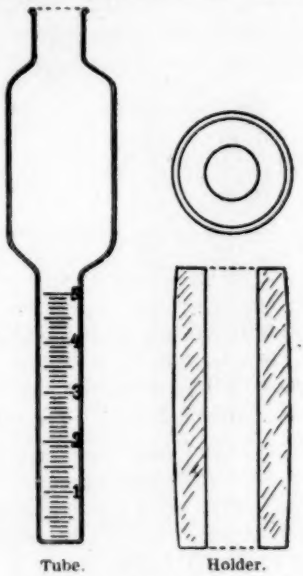
Total length	15.2
Diameter (wide part)	3.0
Diameter (neck)	2.0

Stem graduated to 5 cc and tenths; 5 cc division line 5 mm below beginning of wide part.

Ground area on wide part for use in numbering. Made of pine or white wood.

The tube is provided with a holder having the following dimensions:

	Cm.
Length	7.7
Diameter	3.2 to 3.5
Diameter of center hole, to fit stem	1.3



Tube. Holder.

Plate 16. Hortvet tube and holder.

per minute can be found.* Adopting formula (7) in foot note,

$$N^1 = \frac{\sqrt{47{,}360{,}000.}}{r^1}$$

which gives same force for centrifugal with radius r^1 as Hortvet's centrifugal.

The Hortvet precipitates (Hortvet numbers) vary as follows (twenty-two samples sirup, eighteen sugar, made by Hortvet):

	Minimum.	Maximum.	Average.
Sirups	0.94	1.82	1.26
Sugars	1.18	4.41	2.25

The writer has had difficulty with this method in obtaining concordant results; samples known to be pure giving very low results, and samples which by all other tests showed adulteration, gave as high as 1.3 Hortvet number; in some samples it is also quite difficult or impossible to get duplicates that agree. The results of cöoperative work by seven chemists† are as follows:

	Sirup 1.	Sirup 2.	Sugar 1. (All Pure.)	Sugar 2.
Average	0.95	1.79	2.38	1.83
Maximum	2.15	2.50	3.79	2.90
Minimum	0.40	1.23	1.41	0.89

These differences are too great to consider this method sufficiently accurate for use by different operators on the same sam-

*Hortvet's method is found in Bul. 107, Bur. Chem., p. 72, as a provisional method. In this Bul. on p. 73, it is stated that the value for F (force) in the above formula becomes 138,378, using 18.5 for radius (r) and 1600 for velocity (v) and solving the formula $F = \frac{v^2}{r}$. The numerical expression 138,378 obtained for F by this formula is incorrect, since v is used for "revolutions per minute," whereas it should be used for peripheral velocity, which depends upon two variables, radius and revolutions per minute. The writer suggests the following formula: Since F^1 for any centrifuge used is to be the same as that used by Hortvet, we have—

$F = F^1$ - - (1) or

$\frac{M\ v^2}{r} = \frac{M^1\ (v^1)^2}{r^1}$ - - (2) or

$\frac{v^2}{r} = \frac{(v^1)^2}{r^1}$ - - (3)

since $M = M^1$

$v = 2\ \pi\ r\ N$ - - (4)

N being no. of revolutions.

Subs. v in (3)

$\frac{4\ N^2\ \pi^2\ r^2}{r} = \frac{(4\ N^1)^2\ \pi^2\ r^2}{r^1}$ - (5)

$N^2\ r = (N^1)^2\ r^1$ - - - (6)

$N^1 = \sqrt{\frac{N^2\ r}{r^1}}$ - - - (7)

r^1 = radius of new centrifuge

N^1 = no. of revolutions required

†Proceedings 22d An. Con. A. O. A. C., p. 42.

ples; in fact, some of the analysts reporting above got results that are not comparative even for the same analyst. The associate referee (Mr. Hortvet) says that he has never regarded the method otherwise than as quick and approximate. The writer is convinced, from experience, that differences in results are due to differences in reagents and in whirling; it is almost impossible to prepare the reagents exactly alike each time; and it is quite impossible to give each determination the same amount of whirling. Among the writer's first experiences with this method are the following results on three different sirups, in triplicate:

Sample A	B	C	Blank.
2.16	2.75	2.85	.35
2.50	1.80	2.15	.30
2.35	2.45	3.10	.40

Using this method on commercial samples of maple products, the writer has obtained the following results:

Hortvet number.	Complete analysis showed sample to be:
0.1	Adulterated
0.5	"
0.2	"
0.6	"
2.1	Partly maple.
3.4	Pure.
2.0	"
2.0	"
2.3	"
3.0	"
2.0	Adulterated.
0.4	"
0.3	"
3.0	Pure.
0.2	Adulterated.
3.0	Pure.
0.4	Adulterated.
3.5	Pure
5.0	"
3.5	"
0.6	Adulterated.
0.6	"
3.0	Pure.
0.5	Adulterated.
2.3	Pure.
0.7	Adulterated.

CANADIAN METHOD.*

In this method the weight of the lead subacetate precipitate is determined as follows: 5 g. of sirup or sugar are weighed into a large test tube and dissolved in 20 c.c. water. Add 2 c.c. subacetate of lead solution (Sp. gr. 1.26) (Official, A. O. A. C.) mix, let stand two or three hours, filter into a sugar tube, wash four or five times with warm water, dry and weigh. The result is expressed in grams per 100 grams of dry substance. Assuming the average amount of dry substance in sugar to be 90% and in sirup 65%, the weight of lead precipitate from sugars is multiplied by 22.22 and from sirups by 32.5 to obtain weight per 100 grams of dry substance. Genuine products give above two grams lead precipitate per 100 grams dry substance; doubtful samples give between 1.8 and 2.0 grams, while adulterated samples give less than 1.8.

This method gives satisfactory results in the Canadian laboratory where a great many samples of sirup and sugar are analyzed annually. In connection with this "lead precipitate" determinations are also made of ash, and in doubtful cases, malic acid value.

Averages† taken from the Canadian Bulletins show that in pure products there is a relation between "lead precipitate" and "ash," which is an indication in doubtful cases. Pure products give the following:

Lead Precipitate.		Ash.
Range.	Average.	Average.
2.0-2.5%	2.38%	0.65%
2.5-3.0	2.73	0.68
3.0-3.5	3.26	0.77
3.5-4.0	3.60	0.81
4.0-4.5	4.19	0.90
4.5-5.0	4.71	0.97
5.0-5.5	5.25	0.97
5.5-6.0	5.71	1.06

The writer has used this method with good results; discrepancies in results by this method are due principally to the danger of not washing out all sugar, or washing too much and in that way

*Bul. 140, Inland Revenue Dept., Ottawa, Can.

†Compiled by the writer.

dissolve some of the lead precipitate, lead malate being somewhat soluble. The amount of water to be used for washing should be specified. The writer's results by this method are as follows:

Lead precipitate.	Complete analysis showed the sample to be:
0.0	Adulterated.
1.1	"
2.4	"
2.2	"
3.7	"
5.5	Pure.
4.2	"
0.9	Adulterated.
1.7	"
1.6	"
5.8	Pure.
0.9	Adulterated.
4.9	Pure.
0.0	Adulterated.
6.6	Pure.
7.6	"
5.1	"
1.6	Adulterated.
2.2	"
1.6	"
4.5	Pure.
4.5	"
1.9	Adulterated.

It appears from these results that the minimum for pure products should be somewhat higher than 2.0.

WINTON METHOD.*

In this method the amount of lead precipitated by a maple product is determined as $PbSO_4$ and calculated to lead in 100 grams of substance. The process is as follows: Weigh 25 grams into a 100 c.c. flask; add 25 c.c. standard lead subacetate solution, fill to mark, shake, let stand one hour, filter. Take 10 c.c. of the filtrate, dilute to 50 c.c., add moderate excess H_2SO_4, also 100 c.c. of alcohol (95%), let stand over night, filter

*Jour. Am. Chem. Soc., 28, p. 1204.

on Gooch, wash with alcohol, dry, ignite to low redness for three minutes, cool and weigh. Calculate to Pb, and subtract this from the Pb found in a similar manner in 2.5 c.c. of the standard lead subacetate solution, and multiply* the remainder by 100; this result gives the *"lead number."* The standard lead solution is made by adding four volumes of water to the A.O.A.C. official† lead subacetate solution.

This method gives good comparative results; these results are not absolute, since they are subject to variations due to volume of precipitate produced, which in some cases is quite large; if any error is introduced it appears in the result multiplied forty times; like in all other lead precipitate methods mentioned so far, it is also subject to variation in samples where fermentation has produced CO_2. The method has advantages over those in which the volume of precipitate is measured, both in manipulation and accuracy of results.

The writer obtained the following results:

Winton number.	Complete analysis showed the sample to be:
0.13	Adulterated.
0.22	"
0.10	"
0.11	"
0.55	"
1.24	Pure.
1.54	"
1.46	"
1.29	"
1.33	"
0.24	Adulterated.
0.36	"
0.31	"
0.06	"
1.49	Pure.
1.10	"
1.80	"
0.01	Adulterated.
0.03	"

*In Winton's description he omitted stating that remainder should be multiplied by 100.

†Bul. 107, p. 40.

1.91.....Pure.
1.65..... "
1.29..... "
1.23..... "
0.28.....Adulterated.
0.48..... "

HILL AND MOSHER METHOD.

Several years before Jones or Hortvet published their methods, Professor H. M. Hill, of the University of Buffalo, had worked out and was using a method in which he decomposed the lead precipitate with H_2S and determined volumetrically the acid radicals which were combined with the lead;* the acids were all calculated and reported as malic acid. Professor Hill used this method with great success in a great many court cases years before other chemists would undertake to prosecute adulterated maple products.

Dr. Hill has never published this method, although a few other chemists knew it as early as 1904.† As originally used, it is as follows: Take 50 c.c. sirup, dilute with 200 c.c. water, add drop by drop to slight excess, a saturated solution of neutral lead acetate, warm gently to coagulate the precipitate, let settle, filter, wash free from lead acetate; transfer filter and contents to beaker, add water and pass H_2S through; filter, wash, boil out excess H_2S from filtrate, cool, titrate with tenth-normal NaOH, using cochineal indicator. Pure sirups give a colorless or nearly colorless filtrate from the PbS; adulterated samples give brown or black filtrate. Genuine sirups require from 15 to 18 c.c. of tenth-normal NaOH per 50 c.c. of sirup, corresponding to 0.20 to 0.25 g. malic acid per 100 c.c. of sample. All samples known not to be maple required less than 10 c.c. tenth-normal alkali per

*Blythe, in "Foods, their Composition and Analysis," p. 110, says: "It has been proposed to precipitate the sugar with acetate of lead, and thus obtain the lead salts of the organic acids. The lead compounds are decomposed in the usual way, and the acids set free titrated by potash." The Hill and Mosher method is therefore an adaptation of this idea for the determination or organic acids in maple products.

†A reference to this method is found in "Technology Quarterly," 1905, p. 146. Prof. Woodman here reports some results obtained by this method.

100 c.c. sirup. If pure maple sirup be diluted with granulated sugar sirup, the only change in results noted is the lower acid figure.

As will be noted from this description, the color and clearness of the filtrate from the PbS as well as the number of cubic centimeters of tenth-normal alkali required are the indications of the purity of a sample.* In the following table there is given some of the first work by the authors of this method. The "malic acid" is obtained from the titer by multiplying the number of c.c. of tenth-normal alkali by .0067:

Lab. No.	PbS Filtrate	Malic Acid	Polarization		Remarks
			Direct	Invert	
7876	Nearly colorless	0.210			Pure Sirup, made in Lab.
7934	Brownish	0.243			" " " " "
7976	Nearly colorless	0.209			" " " " "
9004	Colorless	0.247			" " " " "
9085	Colorless	0.267			" " " " "
9108	Colorless	0.203			" " " " "
8728	Black	0.039	+ 64.1		No maple
8729	Brown	0.146			" "
8805	Black	0.023	+ 88.7	+ 61.8	Mostly glucose
8806	Black	0.045	+ 83.8	+ 64.5	" "
8807	Black	0.024	+ 86.2	+ 54.1	" "
8808	Black	0.025	+ 35.7	0 0	Cane + invert sugar
8809	Black	0.025	+ 39.8	— 14 6	Contains glucose
8811	Brown	0.030	+ 36.3	— 14.2	" "
8812	Black	0.035	+ 77 0	+ 36.6	" "
8813	Black	0.029	+ 101.0	+ 74.5	Mostly glucose
8814	Black	0.000	+ 82.6	+ 57.3	" "
9131	Light brown	0.122			40 % Cane sugar

*If the first, or lead acetate precipitate, is granular and white, or nearly so, and settles quickly, this is mostly lead malate and indicates a pure sample. Adulterated samples produce a flocculent, bulky precipitate which settles slowly; it consists mostly of coloring matter and resins.

avoided, the method being gravimetric instead of volumetric. Since completing the work on the gravimetric method, the writer

SIRUPS

Lab. No.	Lead acetate precipitate	Pb S Filtrate	Time M/10 alk.	Malic Acid	Total Ash	Color of Ash	Water sol. Ash	Insol. Ash	Alk. sol. Ash cc/10@9	Alk. insol. Ash cc/10@9	Remarks
10201	+, light	clear	2.7	0.018	0.05 %						Very little maple
10202	+, light brown	clear	20.9	0.140	0 35	green					Pure maple
10203	-, brown	turbid	2 5	0.017	0.11						Adulterated
10204	—, dk. brown	turbid	1.6	0.011	0.05						No maple
10188	—, brown	turbid	2.3	0.015	0 37						Maple and cane
10306	+, lt. brown	clear	37.3	0.250	0.31	green					Pure maple
10307	+, dk. brown	turbid	0.6	0.004	0.04	trace green					Little maple
10308	+, lt. brown	sl. turbid	12.9	0.086	0.37	green					About 50% maple
10309	trace	turbid	0.3	0.002	0.01						No maple
12220	+, white	clear	35.0	0.175	0.46						Pure maple
12221	+, brown	clear	24.9	0.167	0.47	green	0.30	0.17	0.32	0.38	Cane with little maple
12222	—, dk. brown	turbid	3.7	0.025	0.69	green	0.52	0.17	0.62	0.45	Cane with trace of maple
12223	—, brown	turbid	10.1	0.067	0.65	green	0.56	0 09	0.63	0.32	Cane and maple
12224	+, lt. brown	turbid	12.4	0 083	0.49	green	0.33	0.16	0.33	0.42	Cane and maple
12226	—, v. dk. br.	turbid	11.0	0.074	0.83	green	0.66	0.17	0.74	0.31	Partly maple
12227	—, dk. brown	turbid	6.5	0.043	0.68	green	0.53	0.15	0.61	0.39	Little maple
12129	—, brown	turbid	6.7	0.045	0.19	green	0.11	0.08	0.26	0.40	One-third maple
12130	—, brown	sl. turbid	2.8	0.019	0.62	green	0.32	0.30	0.44	0.45	About one-tenth maple
12131	—, brown	turbid	3 6	0.024	0.81	green	0.75	0.06	0.75	0.20	Little maple
12358	+, light	clear	29 8	0.200	0.46	green					Pure maple

so, and settles quickly, this is mostly lead malate and indicates a pure sample. Adulterated samples produce a flocculent, bulky precipitate which settles slowly; it consists mostly of coloring matter and resins.

Soon after Hill and Mosher began using this method, the writer became connected with Dr. Hill's laboratory and analyzed a great many samples of maple sirup and sugar; the main indication as to purity of the sample was that obtained by this method, which, of course, was supplemented by other analytical data. As will be seen from the following table and discussion, the Hill and Mosher titer was not always a reliable indication; this was due chiefly to the fact that in some cases the filtrate to be titrated with alkali and cochineal was too dark in color for observing the end reaction accurately; another reason was that specific directions were not given or followed as to amount of water to be used in

Plate 17. Maple grove during sugar season.

washing the lead acetate precipitate, the latter being somewhat soluble in cold and more so in hot or warm water; since the filtrations were sometimes made before the solution had cooled and then washed with varying amounts of water, the amount of lead precipitate dissolved and lost in this manner was too great to be ignored. In the writer's method, to be described later, account is taken of the solubility, experiments being recorded to show solubility. The troublesome end reaction in dark filtrates is entirely avoided, the method being gravimetric instead of volumetric. Since completing the work on the gravimetric method, the writer

has discovered a process by which dark filtrates from PbS in the Hill and Mosher method may be titrated and a good end reaction obtained. The color of filtrates from H_2S precipitations is due in many cases to suspended or colloidal sulfids; the writer found that by adding chloroform or carbon tetrachlorid and shaking, these filtrates from the lead precipitate became clear enough for observing the cochineal end reaction.

The somewhat incomplete table opposite page 352 gives the results of some of the early work when the Hill and Mosher method was first used.

The conclusions given under "remarks" were based almost entirely upon the Hill and Mosher titer and malic acid; if a complete analysis, including the more recent tests, were made on some of these samples, the conclusions would probably be modified. The total ash in Nos. 12221, 12222, 12223, 12224, 12226, 12227, 12130 and 12131 is sufficiently high in each case for a pure product, each having also the characteristic green coior; some of these appeared to be pure, judging by the Hill and Mosher malic acid. Samples 10202 and 10306, which were called pure, have a very low ash, which may be due to prolonged heating. In a number of samples where the results did not appear concordant, it was customary to repeat the Hill and Mosher titer; frequently these duplicates would agree fairly well; sometimes however there was considerable difference.

Titer, c.c./10 alka'.

No. 10201 gave..... 2.7 and 0.6
No. 10202 gave.....20.9 and 31.5
No. 12221 gave..... 7.5 and 24.9
No. 12224 gave.....18.4 and 12.4 and 22.6

The only other results on record by this method are those of Woodman,* who says, that while this test is rather tedious and disagreeable, it gives characteristic results; that the color of the PbS filtrate was very striking and served excellently to differentiate the impure samples.

(To be continued.)

*Tech. Quarterly, 18, p. 152.

Section of Mining and Metallurgy.

(Stated meeting held Thursday, October 1st, 1908.)

Opening Address.

Opening Address of Prof. A. E. Outerbridge, Jr.,

President of the Mining and Metallurgical Section.

The speaker gave a resumé of the progress in the Metallurgical Arts during the past two years, and said that the principal advances noted by him within that period have been along the lines of perfecting various new processes that had been previously discovered and announced to the world.

In the working of steel, for example, astonishing results in increased speed of cutting, planing, turning, filing and machine finishing generally of this metal have come from the substitution of so-called "alloy-steels" in place of "carbon-steels'" heretofore used for cutting tools. Formerly a carbon steel tool which would cut off great chips from a rough forging of a shaft, or an anxle, when turned in a lathe, at a speed of thirty to thirty-five feet per minute without having its cutting edge destroyed in a short time was considered a first-class tool, but such puny records are not tolerated at all to-day. The speaker exhibited a cutting tool of tungsten-steel, which was used as a "roughing tool," for cutting or turning off the rough surface of a soft steel shaft 6½ inches in diameter, at the extraordinary rate of 95 feet per minute, the steel chips being ¼ of an inch thick (¼ to ⅜ inch depth of cut, 1/16 inch feed), the cutting continued for nearly an hour without destroying the tool, notwithstanding that it became red hot on the "nose" or lower end, while the steel chips were too hot to touch and assumed a bright blue color from oxidation.

In 1905 the speaker announced before the Matallurgical Section

of this Institute a new discovery in the treatment of cast-iron while in the molten state, after it had been withdrawn from the melting furnace, whereby the strength was increased and at the same time the ordinary brittleness and hardness of cast-iron was largely eliminated. The process consists simply in adding to the molten metal, just before pouring it into the moulds, a very small quantity of an alloy containing fifty per cent. or more of the element called silicon. This alloy is a comparatively new product now being made in the electric furnaces with intense heat and was at first only used for treating molten steel in quite a different way for a totally different purpose. At the time this new announcement was made, three years ago, there was practically no demand for the alloy in the six or seven thousand foundries in this country engaged in making iron castings, but since the publication in the *Journal* of the Franklin Institute in December, 1905, of the results of the speaker's experiments and investigations with "Ferro-Silicon in the Foundry," a rapidly increasing use for the high-grade silicon alloy in iron foundries in this country, and also in Europe, has sprung up, the beneficial effects being found greater than was at first claimed.

The next topic discussed was the recent investigations into the character and composition of the moulds into which molten iron and steel are poured, and samples were shown of the various crude materials, such as moulding sand, carbon dust, etc., from which such moulds are made, together with the finished products (in the form of moulds and cores) that were actually strong enough to be passed from hand to hand and roughly handled without injury. A modern "centrifugal process" for mixing the heterogeneous compounds used in making moulds was described and pictures were thrown upon the screen showing the machines and the products.

The reduction in cost of making moulds and cores by moulding machines, in place of hand moulding, was stated to be more than fifty per cent. in the majority of cases, where many castings are made from one pattern.

The speaker called attention to the remarkable progress recently made in reducing low-grade metalliferous ores and recovering the metals at a profit, which were formerly of no value, and instanced the recovery by such methods of the precious metals, gold and silver, and base metals, lead, zinc, etc., from

"tailings" that were cast aside at the mines and formed huge dumps of refuse.

According to conservative estimates made in 1905, zinc tailings at the Broken Hill field, in New South Wales, alone amounted to 5,700,000 tons, valued at $57,000,000.*

With a view of obtaining a process capable of dealing with this waste material profitably, the various companies in that region offered large monetary rewards for a successful method. Metallurgists all over the world began experimenting, and several radically different, but highly ingenious and practical schemes were devised, some of which are daily at work rapidly recovering this vast quantity of metal now lying fallow, and large as these "dumps" are, they are mere ant hills compared to the mountains of waste tailings at mines in various parts of the world waiting to be treated for the profitable recovery of the metals they contain.

In conclusion the speaker said, that the prospects of increased activity in all metallurgical operations, after a twelve month's breathing spell, are quite encouraging for the coming year, and he congratulated his hearers upon the prospects before them of increased activity in their various occupations. He said, within a few days, indeed, signs of a change in the prevailing "trade winds" have been observed in Pittsburgh and other industrial centers, showing quite a freshening breeze that will, it is hoped, not prove a fitful gust, but will continue steadily increasing in force so that ere many weeks shall have elapsed, we may look back upon the present period of depression as a thing of the past, from which valuable lessons may be learned.

SULPHUR AND PYRITE INDUSTRY IN 1906.

The sulphur industry of the United States during the last few years has been characterized by steady growth in consumption, increase in production, and decrease in quantity and value of imports as a result of the development of domestic resources.

Statistics collected by Dr. David T. Day, of the United States Geological Survey, and published in an advance chapter of "Mineral Resources of the United States, Calendar Year 1906," show that the domestic production increased from 181,677 long tons, valued at $3,706,560, in 1905, to 294,153 long tons, valued at $5,096,678, in 1906. Exports amounted to 22,237 long tons, valued at $460,435.

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*See Engineering Magazine, September, 1908.

The great production of sulphur in Louisiana continued in 1906, and the success of the Frasch sulphur process, by which the mineral is melted by streams of superheated water pumped into the Louisiana wells, has been fully demonstrated. Local demands for sulphur for sheep dip and for use in destroying vegetable parasites have been very well met by developments in Utah, Wyoming, and Colorado.

The dominating factor in the world's supply of sulphur has been the production of the material in Sicily, which, in 1906, showed a large decrease, chiefly due to the loss of the American trade through the development of the Louisiana deposits. The exports from Sicily to the United States have decreased steadily for the last four years—from 155,996 long tons in 1903 to 41,283 tons in 1906.

The pyrite production of the United States increased from 253,000 long tons in 1905 to 261,422 long tons in 1906, but the price declined from an average of $3.71 per ton in 1905 to $3.56 in 1906, causing the total value to decrease from $938,492 in 1905 to $931,305 in 1906.

Pyrite burning entered significantly into the sulphuric-acid business in 1882, when the product was 12,000 tons. In 1885 the product had increased fourfold; five years later it had nearly doubled again, and increase has since been rapid. The growth has been due not only to the cheapness of this source of sulphur but to the use of the cinder in the blast furnace. The dominant position in the pyrite supply is occupied by Virginia, and California and New York follows.

More careful attention to waste products in copper, lead, and precious-metal smelting will lead in the near future to a production of sulphuric acid in such quantities as to affect commercial conditions very appreciably, and these sources of the acid must be taken into account.

PRECIOUS METALS MINED IN 1906 IN SOUTHERN APPALACHIAN STATES.

The southern Appalachian States, including Alabama, Georgia, North Carolina, South Carolina, Tennessee and Virginia, yielded $295,335 in gold in 1906, a decrease of $158,841 from the figures of 1905. The output of the first four States was notably less, and only Tennessee and Virginia reported increases.

North Carolina still shows the largest output—$82,131—and is closely followed by South Carolina, with $78,959. The greatest decrease—$65,860—is shown by Georgia, whose production amounted to only $31,050.

As usual, silicious ores yielded the largest amount, principally from the Hillabee mine in Alabama, the Haile mine in South Carolina, and the Iola mine in North Carolina. The placer gold aggregated $30,000 in round figures.

Of silver 87,765 ounces were produced, a decrease of 29,744 ounces from 1905, the greatest loss being apparent in Tennessee copper ores. The only States having an important output of silver were North Carolina, with 30,769 ounces, and Tennessee with 55,931 ounces. Almost the whole silver output is derived from copper ores.

The gold and silver production of the United States are described by Waldemar Lindgren, geologist, of the United States Geological Survey, in an advance chapter from "Mineral Resources of the United States, Calendar Year 1906," which will be ready for distribution by the Survey some time in December.

(Stated meeting held Thursday, October 1st, 1908.)

Economy in Purchasing Supplies.

By Robert Job,

Member of the Institute.

The purchase of the supplies of a large corporation under present-day conditions has become a most important factor in the successful conduct of the business, and at the opening of the year's work of the Institute, it may be of general interest to consider some of the conditions and precautions which are observed to obtain the greatest efficiency of material at the least possible cost.

At one time high cost was to a certain extent an indication of high quality, but one soon learns without extended business training, that quality sometimes bears an inverse relation to the price, and in any event that the latter can seldom be depended upon as an exact measure of utility.

These facts have lead to an accurate study of the properties necessary to secure favorable service results under different surrounding conditions, and definite standards in many cases have been worked out, detailing in as simple form as possible the requirements necessary to efficient results. These specifications, as is well known, are submitted to the dealers for bids; the orders are placed with the lowest bidder, and a sample of the shipment is taken upon receipt and tested in order to be certain that the material is fully in accordance with the requirements. When below the specified limits, the shipment is rejected and the freight both ways is paid by the shipper.

It is a matter of general observation, that the highest quality of a given material is not by any means necessarily the most desirable in service, and consequently there is often direct loss without corresponding gain when one merely purchases upon this basis with-

out regard to the properties necessary to ensure long life. An example will point our meaning: Let us suppose that freight car paint is desired of good appearance and of great durability. If we select sesquioxide of iron for the coloring matter, as is usually done, it is well known that thirty per cent. or so of oxide or iron will give ample covering or hiding power, and that a larger proportion does not increase the efficiency of the paint as to either color or durability, while the use of relatively cheap inert fillers when of proper physical condition may even cause decidedly increased life. Hence, insistence upon use of pigment consisting solely of sesquioxide of iron, or other coloring matter, is of no practical advantage for such work and would raise the cost of the paint without increasing its efficiency.

If the paint were desired for tinting purposes the case would be different and the greatest possible strength or coloring power would then be specified and would be fully utilized.

From the discussion above it will be clear that specifications to be efficient must be based upon a study of the properties of the material under the conditions which exist in service, and not upon mere trade quality. The prime essential is that a quality be specified which will give the most effective results, and it is equally important that definite methods of test shall be stated, or shall exist, which will enable the purchaser to determine whether the desired properties are present. Specifications which are not systematically enforced are far worse than useless since they may seem to give a measure of security which may be wholly lacking in fact after the first shipment or two.

Having fixed upon the most suitable quality, the price is determined by competition. In some cases the price will be unchanged by the specifications, but generally a higher quality of material will be obtained at a given expenditure. Frequently, however, an astonishing difference in cost occurs as a result of the specifications, and we have in mind an instance in which a certain compound was obtained by this method for one-tenth the former cost. Sometimes a difference of fifty per cent. is obtained, frequently with increased efficiency in service in addition to the reduction in cost.

Some articles largely used are manufactured and sold under trade names, and often the price is out of all proportion to the true value. Many of these materials, such as disinfectants, car

cleaners, boiler compounds, polishes, etc., can be easily made up, often for one-quarter of the regular selling price.

Other materials, as for instance, oils, special alloys, etc., can be obtained under specifications at a market value much below the prices usually charged by the dealers, with generally better service owing to the greater uniformity of the shipments.

One source of great economy in maintenance lies in the systematic study of waste materials. In railroad operation, and in fact in almost any large enterprize many chances for such work exist. An instance of this type in the writer's railroad experience will illustrate the point. A large number of track batteries were in use in connection with the track signals, and as the renewals for these were a large item of expense, a careful study was begun to devise, if possible, some plan whereby the exhausted material might be renewed. The investigation was carried on step by step, and a method was finally worked out upon a commercial scale by which the worn out element was brought back to its original condition at a trifling expense. The other materials used in the renewals were put upon a specification basis, and as a result of the investigation, the cost of the renewals was reduced to less than one-quarter of the former price, with higher efficiency than was originally present.

Sometimes heavy loss results from the purchase of material which is of high grading for the simple reason that the properties present may be radically different from those essential to successful service. At one time we recall that cast-iron wheel centers, cylinders, and other castings were breaking rapidly in service after a comparatively short life, and a careful investigation was made to determine the causes, and put a stop to the loss. A special high silicon low sulphur No. 1 foundry iron was in use, recommended by the furnace people particularly for such work. On investigation it was found that the proportion of phosphorous was much beyond the point desirable in castings exposed to sudden impact, and the high silicon was also a source of weakness for such service. As a remedy, specifications were drawn up placing the limits in the pig iron and in the coke at the points generally recognized as necessary to produce in the castings the desired properties. Also a thorough study of foundry practice was made and methods were introduced for the deoxidation of the iron in order to secure tough, dense metal free from hardness or spongi-

ness. Every carload of the pig iron and of the coke was tested before used, and if not in accordance with the specifications it was rejected.

The new grade of iron was obtained at a lower price than the former quality, and practically a complete stop was put to the difficulties which had occurred, and the life of the castings was very much increased. Thus the higher grade did not have the properties essential to good service, and a large economy was effected by selection of material at lower initial cost but having the desired character.

Still another fruitful source of economy lies in the careful study of failures in service in order to determine the precise cause of the failures and devise methods for avoiding repetitions. The study of defective iron castings has already been referred to and an equally profitable field lies in the investigation of brass castings and babbitt metals. Hot boxes are often a heavy item of expense and repay careful investigation. This difficulty may be due directly to incorrect foundry practice or composition and may be largely remedied by properly enforced specifications. In some cases unsatisfactory service will be due to failure to get a metal adapted to the requirements, and we have in mind an instance in which the cost of a bearing metal was reduced 75 per cent. owing to the fact that an antimonial lead mixture was better adapted to the conditions than the harder and more expensive brass had been. In this case the unsatisfactory results were stopped and decided economy resulted both by bettering the service as well as by the lowering of the cost of the metal.

The thorough study of failures of steel rails opens another line of work by which great economy may be gained in the purchase of material. Steel rails are a large item of expense in the operation of a railroad, and whatever will tend to decrease the failures of the rails and lengthen the life is certain to bring gratifying results not only in economy of operation but also through increased safety. Many types of failures of rails are caused directly by improper practice at the mill, as for instance in failure to crop ingots to sound metal, and as a result fracture or slivering occurs after relatively short service. At times the steel is too soft and the metal cuts out under heavy traffic. These evils can be very largely prevented by carefully arranged specifications and by placing a sufficient force of thoroughly trained men at the mill to be

certain that the provisions are fully carried out. Precautions such as these are comparatively inexpensive and they pay for themselves over and over again in the increased efficiency of the product.

In certain cases the process by which material is made has a decided influence upon the efficiency. A striking example is found in the manufacture of steel. As is well known, many articles of steel are made up by the bessemer process, and the strength and serviceability at times are decidedly decreased by the proportion of phosphorus with its attending brittleness. If made by the basic open-hearth process both phosphorus and sulphur can be largely eliminated and the tenacity of the steel under impact so greatly increased that a much higher proportion of carbon is safe, producing greater hardness and a larger capacity for wear. These facts have an important bearing in the case of steel rails, for soft-brittle steel commonly used in the past, with carbon contents, say of about 0.50 per cent. and phosphurus of about 0.10 per cent, can be replaced by steel in which the phosphorus is reduced to about 0.02 per cent. or less, and we have known of instances in which the two types of rails laid side by side in track showed only one-third the amount of wear in the latter as in the former quality, with the factor of safety and freedom from fracture greatly increased. The cost of manufacture by either process is practically the same. It should, however, be borne in mind that the mere fact that the steel has been made by the basic open-hearth process is no assurance that the quality will be satisfactory, and in consequence the precautions alluded to above are essential to good service.

Our theme might be extended almost indefinitely with illustration after illustration of economy effected by the systematic working of the general plan which has been outlined. The typical examples which have been cited will, however, give a clear indication of the possibilities of the system, and may, we hope, be of some assistance in suggesting means by which costs of operation may be materially reduced.

TREES AS CROPS.

"It is as sure that forest land can be made to grow successive crops of trees under proper methods as that plow land can be made to grow successive crops of wheat," says the Secretary of Agriculture in the part of his annual report wherein he speaks of the National Forests.

This country, which once could boast of forest resources richer than any other nation in the world, has been cutting three times as much timber for a number of years as there is grown, and the consideration of timber as a crop to be carefully harvested has come at a time when many of the virgin forests are already depleted. Continuing, Secretary Wilson says in part:

"Just as American farming has had to develop and is still developing methods adapted to the conditions of each region to make the best use of the agricultural lands, so must the forester learn by scientific study and practical trial to make the best use of our timberland. And the best use means, of course, not merely its best use for the growing of trees. but its best use with reference to all interests directly or indirectly affected by it.

"As time passes, it will doubtless appear that the principles which centuries of experience in older countries have placed at our command can be applied with increasing good results as we grow more familiar with our own special conditions. The issue is sharply between caring for our forests by applying a system of known efficiency, or suffering certain loss not only of the forests, but of usable water and soil as well, through the operation of causes as certain to act as are the rivers to run to the sea."

The Forest Service now has administration over more than 164,000,000 acres of land. This is slightly more than one-fifth of the country's total forested area; the remainder is in the hands of private owners. Nearly all the timberland in the unappropriated public domain is now in the National Forests. This means that it is being protected against fire, theft, and wasteful exploitation, that its power to grow wood and store water is being safeguarded for all time, and that nevertheless, its present supply of useful material is open to immediate use whenever it is wanted. The report says:

"The timber in the National Forests, which is the legacy of the growth of centuries, is now in the truest sense public property, administered for the benefit of the people—primarily for the benefit of the people of the West, since they are nearest at hand, but on the whole, for the benefit of every part of the country, since the welfare of every section is interwoven with that of all others. The communities and settlers adjacent to the forests are safe from any fear of monopoly of one of the chief necessities of civilized man."

The Secretary tells interestingly of how the government manages its timberlands as a trustee. It gives timber away through free-use permits in small quantities to the actual homemaker, who comes to develop the country, and in larger quantities to communities for public purposes. Its system of management is vastly different from that of a landlord. When large quantities of timber are harvested from the National Forests, sales are made to the highest bidder, but under such restrictions as look to the maintenance of a lasting supply answering to the needs of the locality, to be had without favoritism and without extortionate demands based upon the necessity of the consumer.

Mechanical and Engineering Section.

(Stated meeting held Thursday, October 15, 1908.)

The Water Supply of Philadelphia,

With Special Reference to the Filtration Works Now Under Construction.

By John C. Trautwine, Jr.,

Member of the Institute.

With equal propriety, this paper might have been entitled "An Experiment in Socialism." Socialism proposes to take private property and private industries, with or without the consent of the owners (by right of eminent domain, if necessary), and private services, and to administer this property and these services for the benefit of the public. It thus proposes to crush out private initiative, to create an army of public mercenaries, and to interfere, in a thousand ways, with our personal liberties; and all this in order that it may "abolish poverty," a suggestion which arouses our ire or our mirth, according to our temperament.

In our public water supply, all these threats have been carried into execution. Private property and services have been taken for the public benefit; the private enterprise of the water peddler has been crushed out; the Water Bureau has a thousand or two of employees, paid out of the city treasury, and it is the duty of some of these employees to enter our dwellings and places of business, with or without our consent, to pry into the character of fixtures installed at our own expense, and, if these do not meet their approval, to compel us to replace them with others. Health officers are even presuming to dictate to individuals, in what locations they may not use their old-fashioned pumps, and, to manufacturers, what portions of their offal they may not throw into the streams which flow past their doors.

And, worst of all, poverty has been abolished, in so far as a water supply can reach. The man of to-day, who rents a modern house at $12 per month, is infinitely rich, as to water supply, compared with the merchant princes of Philadelphia in 1800. If socialists are permitted to proceed, as they have done since the dawn of civilization, and notably within the last century, the race of paupers will one day be extinct, and our comfortable bourgeois citizens will be left without objects upon which to exercise their benevolence.

SOURCES OF SUPPLY.

The public water supply of Philadelphia has always been taken, it is still taken, and it bids fair always to be taken, from either the Schuylkill River alone, or from the Schuylkill and Delaware Rivers.

The Delaware water shed, above Philadelphia, has an area of some 8000 square miles, and is about 180 miles long, from north to south, and from 20 to 70 miles wide, from east to west. The river rises in the southeastern portion of the State of New York; and, for the greater part of its course, forms the boundary between Pennsylvania and New Jersey. Tide reaches to Trenton, some thirty miles above Philadelphia.

The Schuylkill rises in the anthracite coal regions, near Pottsville, some ninety miles above Philadelphia, by its own windings; and, before reaching Philadelphia, crosses a limestone belt, in the vicinity of Reading, and the broad belt of "new red shale," between Reading and Norristown. Its course lies mostly in rich agricultural country, and passes the large and prosperous manufacturing towns of Pottsville, Reading, Pottstown, Royer's Ford and Spring City, Phoenixville, Norristown and Manayunk, the last named within the Philadelphia city limits. Fairmount dam is now the upper limit of tidal flow; but, before the construction of the dam, the tide backed up to Falls of Schuylkill, where a rapids (afterward drowned out by the building of the dam) gave the place its name.

The anthracite coal mines are indeed socialistically operated, in that the labors of many men are cöoperatively employed for

the supply of coal to the public; but, thus far, the control of these mines has been suffered to remain in the hands of divinely appointed and profit-seeking guardians,* who rule over the divinely-appointed miners, and who conduct the business primarily with a view to profit, and, secondarily, with a view of keeping within the law without unreasonably scaling down said profits. The consequence is that enormous quantities of acid mine water and of fine coal dust are washed into the streams which feed the Schuylkill.

So far as the mine water alone is concerned, the individualistic activities of the guardians result rather beneficially to the Philadelphia water supply; for, in flowing over the limestone belt, near Reading, and receiving the calcareous waters of the Tulpehocken and other streams traversing that belt, the river water becomes impregnated with lime, which doubtless would make the water extremely "hard," were it not that, in great part, this lime is neutralized by the sulphuric acid, which combines with it, forming lime sulphate, which, in turn, is precipitated to the bed of the stream, so that the water, when it reaches the city, is not too hard for domestic and boiler use, although still greatly inferior, in the matter of softness, to the Delaware water.

Above the limestone belt, the water, still carrying much free acid, is of a blackish color, when seen in mass, and foamless when agitated, as in flowing through the lock-gates of the Schuylkill Navigation. But, in its passage over the limestone belt near Reading, and owing, no doubt, to the action between the acid and the lime, the water assumes a remarkable and beautiful blue color (which persists for some little distance below Reading), and develops much white foam when agitated.

As to the coal dust, however, the individualistic activities of the guardians are less distinctly beneficial to the Philadelphia water supply. We are only now awakening to the necessity of socialistic forest-protection; and, while we slumbered, individual enterprise (which is at the basis of all our prosperity) destroyed the forests; so that, now, the rain, falling upon the ground, instead of being retained and paid out gradually, rushes at once into the streams, causing disastrous floods. These bring to us, first, the

*A prominent official of one of the great coal-mining combinations recently referred to those of his class as "divinely appointed guardians" of the common wealth in coal lands.

red-shale mud* from the lower reaches of the river, and, a day or two later, the coal dust, accumulated in the upper navigation dams; so that, frequently, a glass of water, drawn from the city faucet, looks like a glass of ink.

The socialist city has taken the matter into the socialist courts, praying for injunctions against the individualist guardians; and seeking to restrain them from polluting the streams by coal dust; and, as these suits were brought many years ago, it is not impossible that some little good may have resulted.

It is only very recently, too, that socialism has presumed to restrain individual liberty in the matter of throwing chemical refuse, and house and farm sewage, into streams furnishing water supply; and, as a consequence, the Philadelphia water, prior to the installation of filtration plants, was unfit for domestic consumption, and the typhoid rate was entirely too high.

Each of the two rivers has its own peculiarities in the matter of pollution. In the Schuylkill, a relatively small stream, flowing through a densely populated region, with many large manufacturing establishments, the water reaches the city limits highly polluted; but it is in great measure protected, by Fairmount Park, by intercepting sewers, and by Fairmount dam, from the city's own sewage. From those portions of the city above the dam, which drain into the Schuylkill, the sewage is carried, by intercepting sewers, into the river below the dam; and one of the principal arguments for the establishment of Fairmount Park was the protection which it would afford to the water supply, by preventing the discharge of manufacturing sewage into the stream by individual enterprise.

In the Delaware, on the other hand, a much larger stream, flowing through a district much less densely settled, the water, although passing through vicissitudes of much the same kind as the Schuylkill, reaches the city in better condition, as regards both softness and purity; but, on the other hand, it has no protection, by park or by dam, from the city's own sewage, or so much of it as falls into the Delaware,—for this is carried up-stream by every flood tide.

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*Those in charge of the filtration plants tell us that the particles of the red-shale mud, brought down by the river, are not only very much finer than the finest coal dust, and therefore much more difficult to manage on the filters, but also finer even than the bacteria themselves.

The Lehigh, an affluent of the Delaware, rises, like the Schuylkill, in the anthracite coal regions, and it and the Delaware traverse the limestone and red-shale beds traversed by the Schuylkill.

Prior to the recent changes, about 90 per cent. of the entire supply was taken from the smaller stream, the Schuylkill; very probably because that happened to be the stream first drawn upon.

On the Schuylkill, the Fairmount, Spring Garden, Belmont and Queen Lane stations draw from the Fairmount pool, formed by the City's dam at Fairmount; and the Roxborough station draws from the Flat Rock pool, formed by the Schuylkill Navigation Company's dam at Flat Rock. The Schuylkill supply is thus dependent upon the integrity of these two dams, except that the Roxborough works are provided with special pumps for supplying the main pumps with water from the river at low stage, in case of failure of the Flat Rock dam, several such failures having rendered its integrity questionable.

On the Schuylkill, the City finds itself in conflict with the Navigation Company, which claims the right to prevent the City from drawing down the levels of the pools below a certain minimum, considered by it as necessary for its purposes.

On the Schuylkill, also, the City is, to some extent, at the mercy of the Navigation Company, by reason of the Company's control of its numerous dams, upon the river and its tributaries, above Fairmount. It is only fair to the Company to remark that its justice has been tempered with mercy, that it has frequently come to the relief of the City by letting down some of its stored water, and that it has even offered to bestow its valuable privileges upon the City—for a consideration. Questioned, by a Council's committee, as to the advisability of accepting this offer, I replied that the offer might be worth considering, if disencumbered from the consideration, but not otherwise, inasmuch as the minimum flow of the river was ample for all the City's needs and luxuries—barring only the luxury of waste.

METHOD OF SUPPLY.

Necessarily the supply has always been by pumpage from the rivers, these of course lying lower than the city itself.

At Fairmount, the oldest *existing* pumping station, the pump-

age is done by water power, derived from the river itself by means of the Fairmount dam and the seven turbines. The quantity required, to force one gallon into the Fairmount and Corinthian reservoirs, has been differently estimated at from fifteen to thirty gallons, the quantity, required for power, depending, of course, upon the relative heights of the water up-stream and down-stream, which, in turn, depend chiefly upon the stage of the tide, and, to a less extent, upon the up-stream level.

Owing to the claims of the Schuylkill Navigation Company, the Fairmount works (which are of relatively small capacity) have been increasingly idle, especially during the low water of summer, and it is now proposed that they shall be abandoned as a working factor in the supply; but it is much to be hoped that they will be retained as an object of picturesque and historic interest. Few if any large cities in the world have, so near their centers, so beautiful a spot as the Fairmount hill and water-works. During the Revolution, the hill was occupied by a British redoubt, one of a series of such structures, which extended from the Delaware, near what is now Fairmount Avenue, to the Schuylkill at Fairmount, north of the then limits of the city. The series was completed by a redoubt at 22d and Chestnut Streets, the site of which was afterwards occupied by one of the two pumping stations of the city's first water works, built by Benjamin H. Latrobe and Nicholas I. Roosevelt (brother to the President's grandfather) in 1799-1801.

With the exception of Fairmount, the pumpage is all done by steam power.

Normally, the pumpage has always been to elevated reservoirs, from which the water flowed, by gravity, into the distribution. Even the first works had one and sometimes two wooden tanks in the dome of the tiny station at Center Square. Later, beginning with Fairmount, earthen reservoirs were constructed on more or less elevated sites. The largest of the reservoirs is that at East Park, with three basins, then that at Queen Lane and that at Roxborough, each with two basins. These are the three large reservoirs. The others are much smaller and are now of but little consequence.

Owing, however, to a cause which will be mentioned later, it has often been found impossible, by means of the pumps, to keep up the supplies in the reservoirs against the excessive demand;

so that, in order to avoid the complete emptying of the reservoirs, it has been necessary to resort to direct pumpage, under which the vile fluid of the Schuylkill was forced direct into the distribution, with not even the trifling benefit of sedimentation in a reservoir. Prior to my administration, this was the normal condition with regard to the Spring Garden works, which supplied the major part of the city and pumped more water than all the other stations combined; but, just prior to my term, the Queen Lane pumping station and reservior had been constructed; and these enabled us to reduce materially this serious nuisance.

Besides the stations which drew directly from the rivers, there were several "high-service" stations, located in elevated positions and supplying limited and generally sparsely settled areas, lying at elevations too high to be supplied from the reserviors. Of these, the principal are those at Belmont, supplying Bala, etc.; at Lower Roxboro, supplying Chestnut Hill; and at Wentz Farm, for the supply of Bustleton and Fox Chase.

The Spring Garden pumping station, already mentioned as the largest, is so called from the fact that its nucleus (located in a building of Egyptian design and still standing) was built by the then outlying district of Spring Garden. The station now comprises an upper and a lower house, the former containing about as remarkable a collection of curiosities, in pumping engine design, as I remember to have seen anywhere, outside of Cincinnati, O. From it issues, on the east, a most complicated net-work of large mains, which, of necessity, pass under the numerous tracks of the main line of the Philadelphia & Reading Railway, which runs close by the station. Breakages in these pipes have caused very serious damage to railway and to station, washing quantities of gravel out from under the tracks and carrying it down into the pump wells of the engines.

Adjoining the Spring Garden station still stand the wooden sheds in which was located the city's first experimental filtration plant.

A table below gives data respecting the several pumping stations and reservoirs as they existed in 1898, and as they will be left by the changes now in progress.

A visitor to our water works to-day naturally wishes first to see at least one of the four filtration plants now completed, or nearly so, as these constitute the novel feature; but, prior to their

construction, he was shown the pumps and the reservoirs, these being, in fact, about all that could be shown; and he was apt to come away with the impression that he had seen the water works, whereas really by far the greater portion of the works was under ground and therefore out of sight. An estimate, made some ten years ago, of the cost of the then existing works, distributed the cost approximately as follows:

Pumping stations	$4,000,000
Reservoirs	6,000,000
Distribution	25,000,000
Total	$35,000,000

CONDITIONS IN 1898.

In order properly to understand the recent extensions, consisting of and in connection with the filtration works, we must first take a glance at the conditions existing immediately before those works were begun.

USE AND WASTE.

Until recently the city's only means of determining the quantities of water handled by the pumps was "plunger displacement." A revolution-counter recorded the number of strokes of each pump; and, knowing the dimensions of the plungers and the lengths of stroke, it was easy to determine the quantity which ought to be discharged at each stroke, and what each pump ought to be lifting. As a matter of fact, owing to defective valves, etc., the quantity actually lifted nearly always falls short of the theoretical quantity, determined in this way; and a deduction is made, from the theoretical quantity, to cover this deficiency. In view of the dilapidated condition of many of the pumps, however, it is altogether probable that the deductions so made were insufficient, and the pumpage therefore exaggerated; possibly by as much as 10 or 15 per cent. Making deductions for this, Fig. 1 may be taken as a fair indication of the growth of the city's water consumption, between the years 1860 and 1897. The upper diagram represents the *total* pumpage, in gallons per day, and the lower di-

agram represents the number of gallons pumped *per capita* per day. It will be noticed that, in the thirty-seven years mentioned, the daily total pumpage (estimated as above explained) increased from 20 to 257 million gallons, an increase of nearly 1200 per cent., and the per capita from 36 to 215 gallons, an increase of nearly 500 per cent.

Market Street is 100 feet wide between house lines; and 250,000,000 gallons would fill Market Street, to a depth of 100 feet,

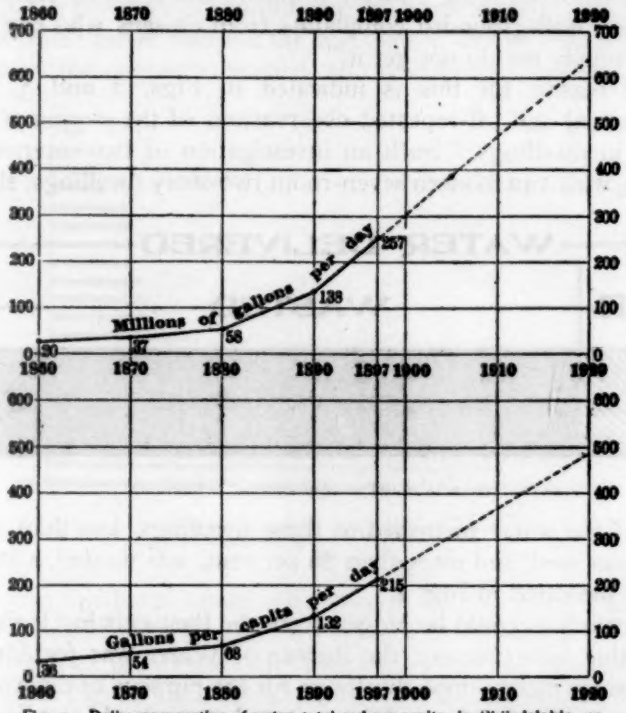

Fig. 1. Daily consumption of water, total and per capita, in Philadelphia, as deduced from plunger displacement.

from the Delaware to 7th Street. The present daily consumption of about 320,000,000 gallons would extend from the Delaware to about 9th Street.

Inasmuch as fifty gallons per capita per day has repeatedly been shown to be a very ample supply, it might be supposed that our citizens, of that time, were deluged with water and complaining of the difficulty of getting rid of it, and that our pumps, if we had

chosen, might have been left standing idle more than half the time.

I quote from my last annual report, that for 1898:

"Our boilers and engines are strained to the utmost night and day, and in some cases disabled; there is no opportunity for thorough repairs; we dare not stop pumping during seasons of muddy water; in spite of all manner of pitiful expedients we are compelled to cut off our reservoirs from the distribution in order to keep them from being entirely emptied; and from all sides come loud and well-grounded complaints from citizens who pay for a water supply but do not get it."

The reason for this is indicated in Figs. 2 and 3, based upon actual and oft-repeated observations of the consumption of water in dwellings. Such an investigation of two intermediate streets, with 142 modern seven-room two-story dwellings, showed

Fig. 2. Use and waste of water in Philadelphia

that, of the water furnished to those dwellings, less than 14 per cent. was used, and more than 86 per cent. was wasted, a state of affairs indicated in Fig. 2.

As nearly as could be judged from the then existing legislation respecting water meters, the Bureau of Water was forbidden to place water meters upon dwellings for the purpose of determining the amounts to be charged for water; but we could not find that we were forbidden to use these devices experimentally; so, after obtaining the consent of the occupants, we placed meters upon twenty dwellings, of different classes. As the use of these meters was purely experimental and did not affect the amounts of the water bills, the consumers were under no inducement to observe more than their usual care in their use of water. The result is shown in Fig. 3, viz., that, of the twenty dwellings, sixteen consumed from 9 to 60 gallons per capita per day, averaging 33

gallons, while the remaining four consumed 142 to 181 gallons per capita per day, averaging 149 gallons.

Figs. 4 and 5 illustrate, respectively, (1) existing conditions as deduced from the foregoing results, and (2) those which might be expected to follow from the general use of water meters.

As indicated in Fig. 4, one person in every five is throwing away, unused, far more water than the other four consume, depriving those four of their proper supply and compelling them to pay for the privilege of maintaining his useless waste.

The water meter compels the one man in five to stop his wasting, saves the quantities wasted, and distributes them among the

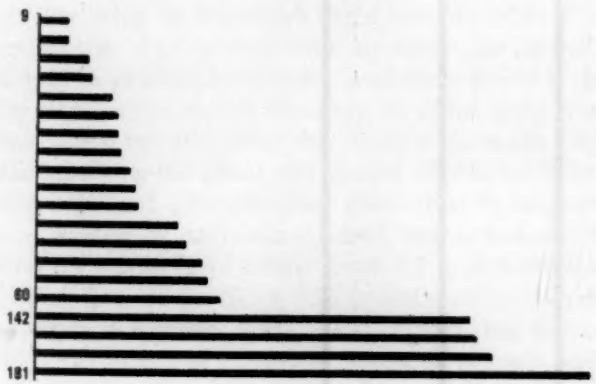

Fig. 3. Consumption of water in twenty Philadelphia dwellings, in gallons per capita per day.

other four, with the result indicated in Fig. 5, viz.: "reduction of bills and increased pressure encourage the liberal use of water." This has been the experience, I believe, wherever the meter has been used. In all such cases, doubtless, the one man in five expostulates, upon the presentation of his first meter bill, and considers the meter an unmitigated nuisance and fraud; but the other four, when they grasp the situation, never fail to sustain the meter. The Mayor of Atlanta, Ga., wrote: "It was a fight, and a sharp one, at first, when we put in the meters and filters. Such, however, has been the effect of experience and education, with demonstration of success, that now I make bold to say it would not be merely a fight, but a revolution, if we attempted to abolish meters and filters."

But, in our community, as in most others where the meter is unknown, the utterly mistaken impression has got abroad that the meter is intended to restrict the *use* of water, whereas, as we have

Fig. 4.

PRESENT CONDITIONS.

More than half the water pumped is wasted by less than one fifth of the people.

Fig. 5.

WITH METERS.

Reduction of bills and increased pressure encourage liberal use of water.

The three tall lines, in Fig. 4, represent, by scale, the water consumptions of the few persons, who, by wasting more than we use, deprive us of the full supply we pay for.

In both figures, the short lines represent the water consumptions of the non-wasters, who are in a majority of at least four to one, but who allow the minority to rob them.

In Fig. 5, these short lines are longer than in Fig. 4, because the water, at present wasted by the few, has been saved, by the meter, and given to the many.

seen, its function is, on the contrary, to *increase* that use by cutting off mere waste and by thus rendering the supply, for use, more abundant.

One irate gentleman asked: "How can we waste what we do not get?" The real question was: "How could he get what the other man was wasting?"

Companies, seeking to capture the Philadelphia water supply, naturally harped upon our inability to meet the demand, and their engineers were not enthusiastic for the meter. With these exceptions, I can recall but one waterworks engineer who opposes the use of the water meter. So far as I know, he has the opposition field all to himself.

Placed between the devil and the deep sea, between our inability to keep a sieve full, and the demand of the people that it be kept full and overflowing, and knowing that the water meter would quickly bring us from dark night into day-light, I naturally advocated its use. I knew that, with the meter, the capacity of our works would be practically doubled, and there would be plenty of water for all; that the cost of filtration, or of bringing water from a distance, would be cut in two; that, even without the adoption of means for purifying the water, the quality of that furnished would be at once improved (for pumping could then be stopped during seasons of muddy or coal-dust-polluted water, and the water in the reservoirs would have longer time for sedimentation); that the minimum flow of the Schuylkill would once more greatly exceed the city's maximum draft upon it, and that the improvement and development of the supply would be brought well within the city's own means. I knew that, in restriction of *waste* (*not* of *use*), the city held, in her own hands, the key to the solution of her water problem, and that she required no assistance from the benevolent corporations which were seeking to relieve her of the the burden of her water works.

But my advocacy of the water meter merely alienated the good graces of citizens who were agitating for improvement of the supply, and who, fearing the ignorant clamor and opposition sure to arise upon the mention of the word "meter," did what they could to suppress all mention of the subject.

FILTRATION.

The quality of the supply has been already discussed. For improvement in this respect, I urged filtration, rather than resort to distant sources, and asked that an experimental filter plant be

established at one of the smaller pumping stations on the Schuylkill, and at the small Lardner's Point station, on the Delaware; these experimental plants to be made up each of several units, representing the best and most favorably known systems of the day. I was profoundly impressed with the facts that filtration was then in its infancy, and that each river and each set of conditions is a law unto itself, requiring careful separate study and experiment, in order to ascertain the best method of treatment.

This proposition met with but little if any more favor than the proposition to use meters. We were told that, if a beginning were made on one or two stations, without completing all simultaneously, the unfiltered districts would be up in arms; we were told that experiment would delay matters and that the entire work must be done as rapidly as possible, and we were asked whether filtration "had not passed the experimental stage." That was ten years ago, and it may be worth while to note, in passing, that the works are not yet completed, and that, although the Roxborough and Belmont works have now been in use for four or five years, the rest of the city, though long supplied with raw water, has not yet risen in insurrection.

There was much ignorant opposition to filtration in general, and the opposition has not yet died out. People still run about, saying that "they will never drink 'filtered filth,' " that "filtration may clarify water, but it does not purify," that "the bacteria in water can march, 1000 abreast, through the interstices between the grains in the sand filter," and that "Philadelphia will never have a proper water supply until she goes to the Delaware Water Gap for it."

It is indeed true that the bacteria are so minute that armies of them can pass between the sand grains; and, for that reason, the water first passed through a freshly-cleaned sand filter is allowed to run to waste—it is imperfectly purified; but, as the water passes between the sand grains, bacteria and organic matter are detached from the water and adhere to the sand grains. The upper portion of the sand layer thus soon teems with such matter, and, in this "Schmutzdecke" (filth-cover) the purification takes place by means of chemical and bacteriological processes which are, I believe, as yet only imperfectly understood; but it is perfectly well known that sand filtration, properly conducted, removes usually from 97 to 99 or more per cent. of the bacteria in the water, and

that its use is almost invariably attended by a very great reduction in typhoid and other water-borne diseases.

A slow filter (See Fig. 8) is simply a bed of sand resting upon layers of coarser sand, gravel and broken stone. These increase in coarseness from top to bottom, the open spaces, in each layer, being of course too small to pass the solid particles of the layer next above. The whole is underlaid by a system of drains, carrying off the filtered water. The raw water rests upon the sand above. In practice, of course, many details and appurtenances are required, especially for the proper regulation and recording of the flow through the filter.

As already remarked, the water, first passed through a freshly cleaned filter, is but imperfectly purified, and is therefore commonly run to waste; the real purification taking place in the upper portions of the sand bed, where a certain quantity of bacteria and other organic matter has been deposited by the water already passed. In a month or so (the time varying with the character of the water) the upper portion of the sand becomes so clogged, by the material thus deposited within it, that it can no longer pass the water with sufficient rapidity. The top sand must then be shoveled off, removed from the filter bed, and either wasted, or cleaned and replaced upon the filter bed, depending upon whether the supply of sand is so abundant as to make wasting the more economical process. In our case it is more economical to wash and replace it. The dirty sand is removed from the beds by means of hydraulic ejectors, and is washed in sand-washing courts by special apparatus provided for the purpose.

The rapid filter is often called the "mechanical" filter, because, in it, the washing of the sand (which is performed in the filter itself by reversing the flow of water through the filter, and sending it through under pressure), is often assited by revolving rakes, operated by machinery. In the rapid filter, a coagulant, usually alum or alumina sulphate, is commonly used. The alum is decomposed, the flocculent alumina settling slowly through the water, carrying down with it the bacteria and other organic impurities. These filters give results fairly comparable with those given by slow filters, and at much higher rates, measured in gallons per day per unit of filtering surface. They are in use in many places, with excellent results, although the necessity for the use of coagulants, in order to secure the high rates of filtration, is generally considered objectionable.

Formerly the rapid filter was always a cylindrical or nearly cylindrical wooden or steel tank, a form favorable to the operation of the revolving rakes; but, more recently, and notably at Little Falls, N. J., and at Harrisburg, Pa., the rapid filters are rectangular in plan; the revolving rakes are dispensed with; and, in washing the bed, it is agitated by currents of compressed air, forced upward through it. It is proposed to use filters of this type as "scrubbers" at Torresdale and at Queen Lane.

STATESMANSHIP.

I have mentioned the benevolent corporations (popularly known as "water snakes") which kindly came forward, in this hour of the city's distress, and graciously offered to lift (for substantial considerations) this water works incubus.

Among these stands out prominently the Schuylkill Valley Water Company, whose scheme was being victoriously rushed through Councils, when an exposure of bribery, on the floor of Councils, threw the fat in the fire, and the scheme passed silently from the gaze of men.

That such a trifle could be made to defeat such a scheme shows that the harmony, which has since reigned in the "organization," had not yet been effected. On the contrary, Mayor Warwick's administration found itself opposed by this organization (then only a powerful "faction"), which decreed that all appropriations for water works improvement should be held up until this faction came into supreme control. The result is seen in the following comparison of estimates for extensions and improvements, and the corresponding appropriations:

FOR EXTENSIONS AND IMPROVEMENTS.

	Estimates	Appropriations
For 1896	$2,484,150	0
For 1897	3,339,450	0
For 1898	3,735,050	0

We were told that the city had reached the limit of her borrowing capacity.

THE NEW ERA.

But, with the advent of Mayor Ashbridge, as the agent of the "organization," in April, 1899, the scene shifted. Real estate values were re-assessed, and it was announced that the city could borrow all the money needed for extensive improvements.

THE COMMISSION OF 1899.

Mayor Ashbridge called in a commission, consisting of Messrs. Rudolph Hering, of New York; Samuel M. Gray, of Providence, R. I., and Joseph M. Wilson, of Philadelphia. The resolution of Councils, under which these experts were appointed, provided that they were "to act in conjunction with the Director of the Department of Public Works, and the Chiefs of the Bureaus of Water and Survey." Under Colonel William Ludlow, Chief Engineer of the Water Department, in 1883-5, Mr. Hering, with an able corps of assistants, had made a very exhaustive study of the question of a supply of water from the Delaware Water Gap and other distant sources. In those days, the flood of light, since thrown upon filtration, had not been shed, and Mr. Hering was therefore quite justified in saying, in his final report, dated July, 1886: " * * nor would filtering or purifying the water of the Schuylkill or Lower Delaware give permanent satisfaction," and that "the only schemes worth investigating were those which bring to the city the water of running streams in the Schuylkill, Delaware, or Lehigh watersheds."

The commission of 1899, like that of 1883-5, was of course given an ample corps of assistants, and the entire summer of that year was devoted to the work, including several all-night sessions on the part of Mr. Hering.

This commission fully re-considered the subject of supply from a distant source, in the light of the surveys of 1883-5, and recommended, as will be seen below, "the adoption of that project by which the waters of the Schuylkill and Delaware Rivers, taken within the city limits, are purified by filtration."

The report was accompanied by plans showing, in a general way, the locations and dispositions of the several works proposed; but the working out of details was of course left to the administration which should construct the works.

The following table shows, in concise form, the estimates of the commission of 1899, of the costs, for construction and for operation, of distant supplies and of a supply by filtration. The cost of operation is given in dollars per annum and in cents per 1000 gallons delivered into reservoirs. It includes interest at three per cent. and depreciation:

	Gallons per day.					
	200,000,000			450,000,000		
		Operation			Operation	
	Construct'n	Annual	Per 1000 gal.	Construct'n	Annual	Per 1000 gal.
			Cents			Cents
Upper Perkiomen and Lehigh River tributaries	$33,410,000	$1,205,000	1.65	$66,740,000	$2,480,000	1.51
Delaware, near Water Gap	47,540,000	.....	.....	83,185,000	2,925,000	1.78
Slow filtration	10,973,591	1,227,373	1.68	34,154,680	2,971,801	1.81

Referring to these estimates, the experts say, in their "resumé and conclusions:"

"The estimates of cost have shown three important results:

(1) The original cost of any of the mountain water supplies is very great for the large quantities of water which the city requires.

(2) A filtered water supply can be obtained at a first cost which is within the present borrowing capacity of the city, and the plant can be operated at a cost which will not exceed the probable annual net earnings of the water works.

(3) The total annual cost of delivering the water into the city reservoirs, by either method, is about the same, and the annual earnings will cover the operation and extension.

In conclusion we recommend:

(1) The adoption of that project by which the waters of the Schuylkill and Delaware Rivers, taken within the city limits, are purified by filtration.

(2) The immediate improvement of the existing plant, in accordance with the detailed recommendations of our report.

The necessity for the second of these recommendations is manifest. Our reasons for the first are as follows:

The entire works can be built for a sum which the city can secure at this time through a loan.

A supply of pure water for the entire city can be obtained within a comparatively short time, and the city can thus at an early day be protected against a continuance of those diseases which are known to be caused by the present polluted water supply.

A filtered water supply, under skilful management, offers a greater security against the effects of accidental pollution of the water than is possible when the supply is taken from open, unprotected water courses.

Filtration can, without difficulty, be made to render the water thoroughly wholesome.

The two large rivers at Philadelphia, or even the Delaware River alone, can furnish at all times a quantity of water sufficient for a very large city."

Fig. 6 is plotted from the foregoing estimates of cost of filtration. The estimates are, respectively, for a supply of 200,000,000 gallons per day, which the Commission considered "a very liberal allowance" for the population (say 1,300,000) of that time, and for a supply of 450,000,000 gallons per day, which the Commission believed would be required by a population of 3,000,000 persons.

Upon Fig. 6, I have scaled the probable costs, for construc-

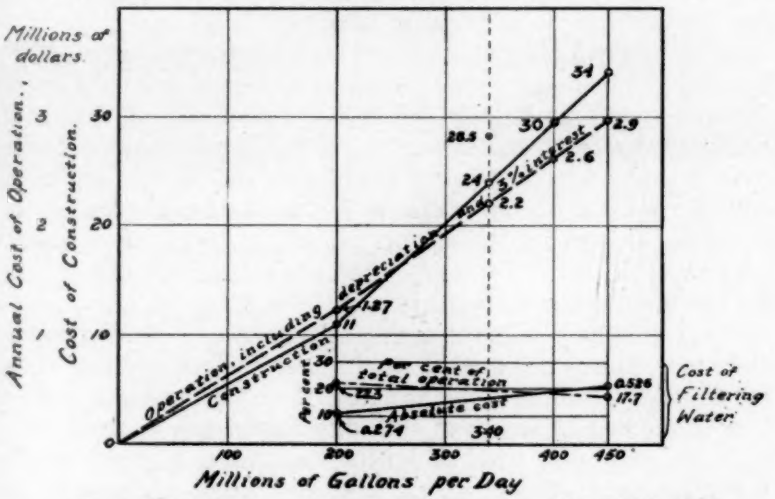

Fig. 6. Estimated costs, for construction and for operation, of slow filtration plants, for Philadelphia; from report of Commission of 1899.

tion and of operation, for 400,000,000 gallons per day (twice the smaller amount contemplated) and for 340,000,000 gallons per day (the capacity of the works as it is expected to be in 1909).

The results for 400,000,000 gallons per day show that, by doubling the consumption, we may expect to more than double the cost of operation, and to considerably more than double the cost of construction.

The results for 340,000,000 gallons per day show that, according to the Commission's estimates, the cost of operation for the entire works next year should be about $2,200,000, of which the

"cost of filtering water" alone should be about $400,000, or a little over 18 per cent. of the whole.

As nearly as we can judge, by scaling from the Commission's estimates, the entire cost of reconstruction, for the works as they will be in 1909, and capable of handling 340,000,000 gallons per day, should have been about $24,000,000. As seen below, the cost of work now finished or under contract, plus estimated cost of work not yet placed under contract, as given me by Mr. Fred. C. Dunlap, the present Chief of the Bureau of Water, amounts to about $28,250,000. Considering that the new works are, in many respects, far more elaborate than the Commission of 1899 ventured to suggest, I regard these figures as indicating that the total cost has been considerably less than might properly have been expected for works of that capacity.

In the body of their report the Commissioners said: "We earnestly recommend the introduction of meters for the City of Philadelphia;" but, in their "résumé and conclusions," the meter was not mentioned, and the shortage of supply was attributed to "the lack of effective pumping machinery, and to the insufficient capacity of the distributing system." The works are planned for a consumption of 150 gallons per capita per day, or only 19 gallons per capita per day less than the Commission's estimate of the actual consumption at that time.

The works have cost, for construction, and will cost for operation, more than double what would have sufficed for a lavishly ample supply, and the people will nevertheless be on short rations.

The building of works of such dimensions was in accordance with the expressed wish of Mayor Ashbridge, that the works might be made sufficient for the next fifty years. A layman can hardly be expected to conceive the rate at which the art of water supply is advancing, or the consequent folly of building for posterity, where, as in our case, there is no necessity for so doing. A great aqueduct is not easily enlarged, and it should therefore be built of a capacity considerably greater than is required by present needs; but the ground, adjoining the Torresdale filter plant, is such that the plant may be increased, a bed or two at a time, as occasion requires. There was therefore no excuse for building for posterity. It merely saddled posterity with a plant which it may not find the best for its needs. However, personal ambition, and the needs of contractors, cannot be expected to be always in harmony with the best interests of the public.

For the immediate future, the Commisison contemplated drawing from the two rivers as follows:

From the Schuylkill—

	Gallons per day.	
At Belmont	27,000,000	
At Roxborough	15,000,000	
At Queen Lane	58,000,000	
At East Park	50,000,000	
		150,000 000
From the Delaware—		
At Torresdale		50,000,000
		200,000,000

The Commission recommended the abandonment of the Lardner's Point station, on the Delaware, and the building of a 50,000,000 gallon station and filter plant at Torresdale.

It will be noticed that this distribution reduced the Schuylkill's proportion of the total supply from 90 to 75 per cent., and all future increase of the supply was to be taken from the Delaware.

The turbine pumps at Fairmount were to be connected with the steam pumps at Spring Garden, for the relief of the latter when the stage of the river would permit.

A rapid filter plant was to be established at East Park reservoir, but slow filtration was to be used for all the rest of the supply.

Where practicable, the existing reservoirs were to be used for the sedimentation of the raw water, preliminary to filtration, except that a portion of their capacity was to be set apart for storage of filtered water. It was considered desirable that the raw water should have at least twenty-four hours for sedimentation, and that there should be stored a half-day's supply of filtered water. All filters and all reservoirs for filtered water were to be covered.

At East Park filter plant, two twelve-million-gallon engines were to be installed, to pump into the Queen Lane district.

At Belmont, the old reservoir was to be used for sedimentation, and it was suggested that, with increase of population west of the Schuylkill, its capacity would have to be increased by the construction of a similar reservoir alongside of it.

THE ADOPTED PLAN.

The plan, actually followed, differed radically, in several important respects, from that recommended by the Commission of 1899, but resembled it in the adoption of filtration and in the diminution of the proportion of water taken from the Schuylkill. On the other hand, rapid filtration has been entirely discarded.

The total capacity of the works, when completed, is expected to be 340,000,000 gallons per day, of which about one-third, or say 115,000,000 gallons, will be taken from the Schuylkill.

The Fairmount works are to be abandoned; the East Park reservoir will be used for the storage of a reserve supply of raw water, and the Spring Garden pumping station will be kept in reserve and used when necessary for keeping up said supply.

The Queen Lane station and reservoir, completed about 1895, are unique in that they form a complete system in themselves; that they were built *de novo,* and not in connection with, or even in proximity to, any other works; and that they have remained without additions. It was at one time proposed to remove its four pumps (as well as several others of the Schuylkill pumps) to the New Delaware station at Lardner's Point; but only one (a large Southwark engine from Roxborough, taken to the old Lardner's Point station) has been moved over, and the Queen Lane pumps are to remain where they are.

Various fates have impended over the head of the Queen Lane reservoir. Immediately after its construction, it got into bad notoriety by leaking as soon as water was turned into it. This afforded a fine opportunity for the opposition newspaper, which bristled with awful cartoons, showing the water gushing in big streams from the structure. During my administration, 1895-9, it, like the Roxborough reservoir, was re-lined with asphalt, and its behavior has since been wholly exemplary; but this did not prevent the chairman of the Water Committee of Councils from remarking, in Committee, a year or two later, that, if the Queen Lane basins had ever been made to hold water, he had not heard of it; and one of the patriarchs of Councils actually introduced a resolution looking to the abandonment of the reservoir and the utilization of the site for building lots. The experts of 1899 recommended a slow filtration plant, to be placed on ground just

north of the reservoir. This would have involved the destruction of the fine old Revolutionary Smith mansion, at which Washington visited. This project was abandoned, and it was later again proposed to abandon the reservoir itself; but it is now intended to build preliminary and main filters over the north basin, the lower part of which is to be the clear-water basin.

At Belmont, three new pumps and additional boilers have been built, and the whole plant is enclosed in a fine new house. In connection with the Belmont filter plant, located practically as the commission proposed, a large new reservoir, for sedimentation, has been built, and the old reservoir is used for storage of filtered water. Preliminary filters have been built.

For Roxborough, the commission of 1899 proposed a filter plant in connection with the upper or larger reservoir only; but filter plants, each with its clear water basin, have been constructed at both reservoirs, and four large new pumps, with new boilers and a new house, have been added to the pumping station at the river.

As already stated, the commission of 1899 proposed a fifty-million-gallon pumping station and filter plant at Torresdale, and the abandonment of the old station at Lardner's Point; but a filter plant of sixty-five beds (fifty-five of which are shown in Fig. 7, with a combined filtering area of fifty acres, and 175,000,000 gallons* daily capacity, has been finished at Torresdale; and the water, delivered by this plant to its clear-water basin, is thence conducted, by gravity, through a tunnel-conduit, 10 feet 7 inches in diameter, 100 feet below ground and two and one-half miles long, to the new monster pumping station, built near the old pumping station at Lardner's Point, which is to be retained in service.

Fig. 8 shows this conduit (one of the most important features of the new plant) in plan and in profile, and, in profile, the 6-ft. brick conduit, built by Latrobe in 1800 for the City's first water works. This old conduit carried the Schuylkill water from the first or Schuylkill pumping station, down Chestnut Street and up Broad Street, to the second pumping station, at Center Square.

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*The "scrubbers," or preliminary filters, shown in Fig. 7 and now approaching completion, are expected to raise the capacity to 240,000,000 gallons per day, as in the table below.

The profile shows the two structures to scale and at their relative elevations, and gives their dimensions, volumes and capacities.

Both tunnels sloped upward, for convenience of flushing. In the Latrobe tunnel, the flow was by gravity, the slope of the water

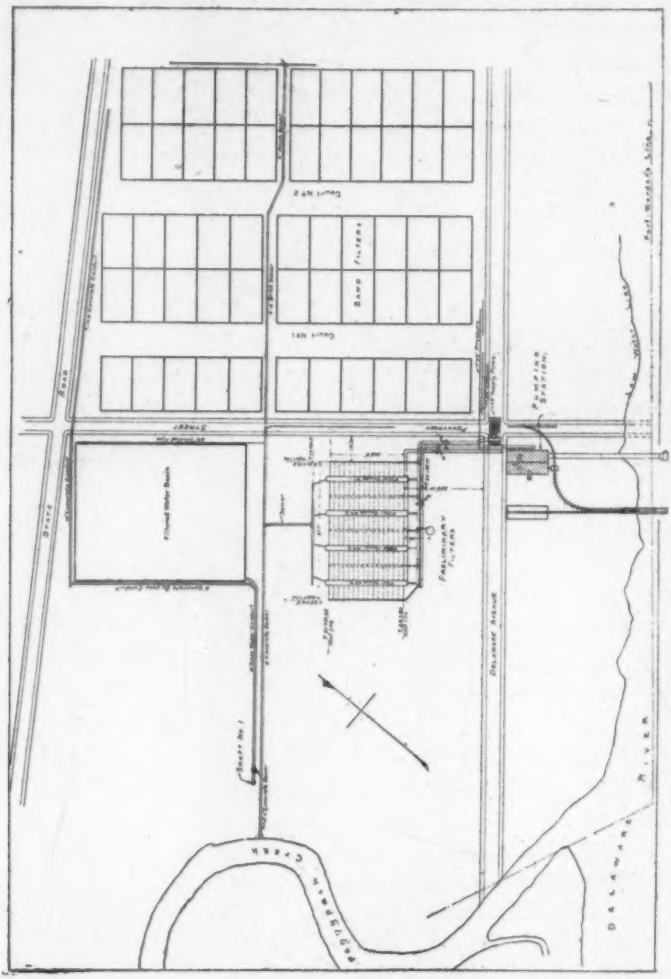

Fig. 7. Plan of Torresdale Filter Plant, showing pumping station, preliminary filters; 55 of the 65 slow filters, filtered water basin, and beginning of Torresdale conduit

surface, from 22d and Chestnut Streets to Center Square, of course producing the flow notwithstanding the slope of the axis of the conduit in the opposite direction. In the new tunnel conduit, driven by Mr. John W. Hill, then Chief Engineer of the

Bureau of Filtration, the flow is caused by the difference of elevation in the clear water basin at Torresdale and in the pump well at Lardner's Point.

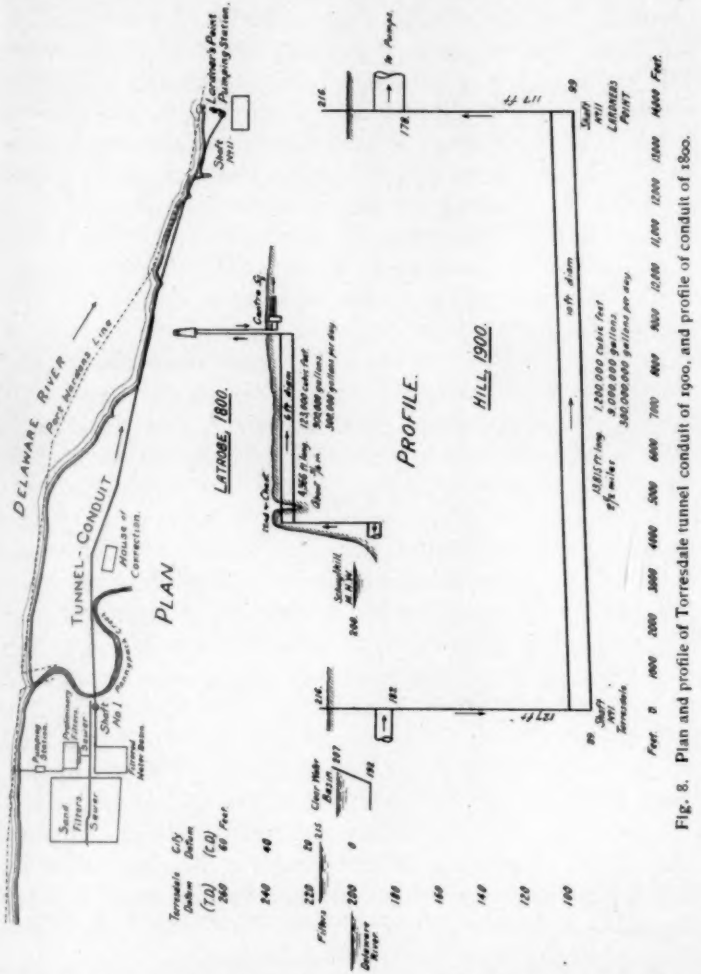

Fig. 8. Plan and profile of Torresdale tunnel conduit of 1900, and profile of conduit of 1800.

Like the Queen Lane reservoir, Mr. Hill's tunnel at once found its way into notoriety through leakage. When this tunnel was emply, it was found that a good deal of water leaked into it; but the conditions were, of course, altogether abnormal. When the tunnel is in service, it is full of water under a pressure presum-

ably greater than that of the ground water outside, so that we may expect a small loss of filtered water, from the tunnel into the surrounding ground. The leakage mentioned occurred when the tunnel was emptied, and the ground water was forced into it by an unopposed external head of probably about 100 feet. In view of this, and knowing something of the difficulty of making large structures watertight against heavy pressure, I could not consider the resulting leakage remarkable; but it was used, to good effect, by some of the more active opposition newspapers, and the matter made its appearance in court, where the bulk of the expert testimony offered pronounced the work excellent, confirming the impression which I had formed upon walking through it, at the invitation of, and in company with, Mr. Hill.

Major Cassius E. Gillette, who succeeded Mr. Hill, drilled very many holes through the tunnel lining, and, through these holes, forced grout into whatever spaces had been left between that lining and the surrounding rock. I believe that this treatment materially improved the condition of the structure.

The new pumping station at Lardner's Point is perhaps the largest on earth. When completed, it will contain twelve vertical triple-expansion pumping engines, each of twenty million gallons daily capacity, pumping against a head of over 200 feet, and supplied with steam by 26 boilers, including 14 water-tube boilers, with mechanical stokers. The pumps and boilers will be sheltered by two great engine houses and two boiler houses, of uniform design, already finished.

At Belmont, at both Roxboroughs and at Queen Lane, the raw water is delivered into the sedimentation basins directly by the high-lift pumps at the river; but at Torresdale a special low-lift pumping plant will lift the river water to the "scrubbers," whence it will flow to the filters, thence to the clear-water basin, and thence, through a short conduit and vertical shaft No. 1, into the tunnel. At Lardner's Point it will rise, through shaft No. 11, to the pump wells of the Lardner's Point pumps.

From Lardner's Point, the filtered water will be sent, by direct pumpage (unobjectionable, of course, with filtered water) into the distribution. The pumping mains are connected with a new reservoir at Oak Lane, but this will serve merely as a stand pipe on the pumping mains, preventing rapid fluctuations of pressure.

PRELIMINARY FILTERS.

An important feature, in which the adopted plan differs from that of the commission of 1899, is the introduction of preliminary filters or "scrubbers."

The slow sand filter, used at all the Philadelphia works, is ordinarily expected to work at a rate of between two and three million gallons per acre per day; but it has been found that, by passing the water first through the relatively coarse filtering material of the scrubbers, and at a correspondingly rapid rate, before admitting it to the main filters, the capacity of the latter can be greatly increased at comparatively small expense, and the "scrubbers" occupy only a small area of ground relatively to that required for the main filters.

At Lower Roxborough, a "scrubber" plant has been built for the Bureau by Mr. P. A. Maignen, of this city. In it, the raw water passes vertically upward, first through a layer of large stones, then through layers of coke, broken into pieces of gradually decreasing size, and finally through a bed of sponge. It then flows to the main filters. From time to time the sponges are washed in machines of the type used in laundries.

At the Belmont "scrubber," also built by Mr. Maignen, the water passes horizontally through beds of coke, and finally vertically through a bed of fine coke breeze.

Both these "scrubber" plants are said to be giving excellent results.

For the "scrubbers" at Torresdale and Queen Lane, the Bureau proposes using rapid filters, of the rectangular type used at Little Falls, N. J., for water purification. The Torresdale "scrubbers" will consist of 120 such filters.

GENERAL ARRANGEMENT.

The Philadelphia filters are all of the usual covered slow type; the roof being formed by flat groined arches, resting upon square pillars, the feet of which are connected by flat invert arches; all as shown in Fig. 9, which represents the construction at the Lower Roxborough plant.

At Belmont and at Lower Roxborough, the water is forced, by the pumps at the river, from the river directly into the sedimentation reservoir, whence it flows, by gravity, through the following course:

(1) Sedimentation reservoir
(2) Scrubbers
(3) Filters
(4) Clear water basin
(5) Distribution;

as indicated in Fig. 10, which shows a rude plan of the Lower Roxborough filter plant.

At Upper Roxborough, the capacity of the sedimentation reservoir is so great, and the sedimentation therefore so effective, that scrubbers have been omitted.

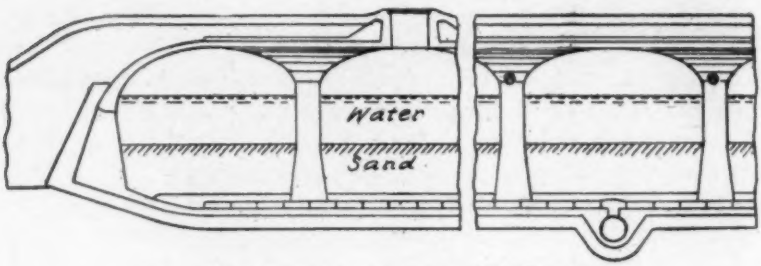

Fig. 9. Vertical section of a slow filter bed, Lower Roxborough

At Torresdale, the Commission of 1899 proposed sedimentation basins, close to the river. To these basins the river water was to be lifted directly by low-lift centrifugal pumps. The present design (Fig. 7) omits sedimentation basins and substitutes scrubbers. The clear-water basin is at a lower level than the distribution, to which, of course, the filtered water could not flow by gravity. It is therefore conducted through the Torresdale conduit, two and one-half miles, to the Lardner's Point pumping station, which forces it directly into the distribution. The reservoir at Oak Lane serves merely as an enlarged stand pipe upon the pumping main from Lardner's Point.

At Queen Lane, the system will have each of the five features mentioned above, and, in addition, low-lift pumps, raising the water from the sedimentation reservoir (the south basin of the

existing reservoir) to the scrubbers, which will be placed over the north basin of the same reservoir.

The table, p. 392, gives, in concise form, a comparative statement of the approximate dimensions and capacities, and the functions, of the several pumping stations, reservoirs and filter plants, as they were in 1898, just before the inauguration of the era of fil-

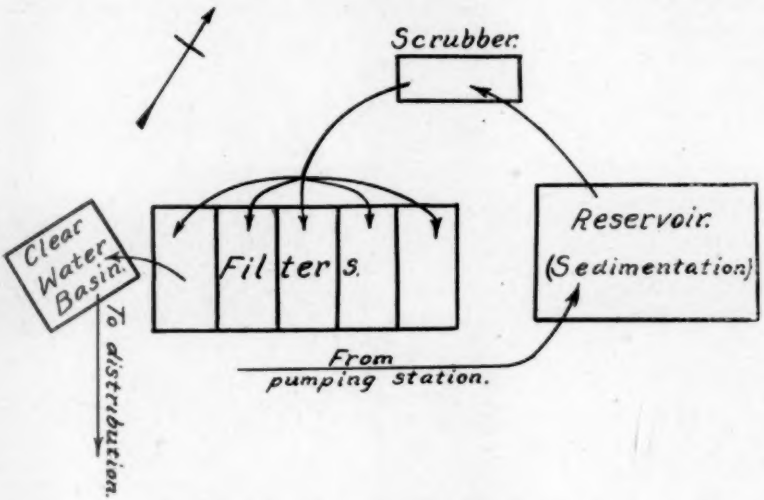

Fig. 10. Sketch plan of Lower Roxborough Filter Plant, showing progress of water from pumps to distribution.

tration, and as they are to-day, or will be when completed, probably early during the coming year. The daily capacities of pumping stations and of filter plants, and the holding capacities of reservoirs, are stated in millions of gallons, to the nearest million. Under pumps, "to Fmt reservr," etc., means *"Pumping to* Fmt reservoir," etc.

PUMPING STATIONS, RESERVOIRS AND FILTER PLANTS, 1898 AND 1908-9.

(The approximate daily capacities of pumps and filter plants, and contents of reservoirs, are stated in millions of gallons, to the nearest million.)

Plants.	*1898.*	*1908-9.*
Fairmount Pump'g Sta.,	7 pumps, 33, to Fairmount Res.	———
Fairmount Reservoir,	26, raw water.	———
Sp. Garden Pump'g Sta.,	9 pumps, 170, to East Park Res.	8 pumps, 150, in reserve, to E. Park, as required.
East Park Reservoir,	689, raw water.	689, raw water.
Belmont Pump'g Sta.,	4 pumps, 38, to George's Hill Res.	6 pumps, 67, to New Belmont Res.
George's Hill Reservoir,	40, raw water.	40, clear water.
New Belmont Reservoir,	———	75, sedimentation.
Belmont Filter Plant,	———	Scrubbers. 18 beds, 50.
Queen Lane Pump'g Sta.,	4 pumps, 80, to Queen Lane Res.	4 pumps, 80, to Queen Lane Res.
Queen Lane Reservoir,	383, raw water.	South basin for sedimentation. North basin for clear water.
Queen Lane Filter Plant,	———	Low-lift pumps, over N. basin. Scrubbers, over N. basin. 22 beds, 80, over N. basin.
Roxboro' Pump'g Sta.,	3 pumps, 25, to Roxboro' Res.	9 pumps, 52, to Roxboro' Res.
Lower Roxboro' Filter Plant,	13, raw water.	13, sedimentation.
Lower Roxboro' Reservoir,	———	Scrubbers. 5 beds, 10.
Upper Roxboro' Reservoir,	147, raw water.	147, sedimentation.
Upper Roxboro' Filter Plant,	———	8 beds, 15.
Torresdale Filter Plant,	———	Low-lift pumps. Scrubbers. 65 beds, 240.
Torresdale Conduit,	———	10′7″ diam., 2.5 miles long, carries clear water to Lardner's Point.
Lardner's Pt. Pump'g Sta.,	3 pumps, 42, to Wentz Farm Res.	16 pumps, 297, direct pump'ge, clear water.
Wentz Farm Reservoir,	36, raw water.	36, clear water.
Oak Lane Reservoir,	———	On pumping mains from Lardner's Point.

THE COST.

The cost of construction, as given me by Mr. Fred. C. Dunlap, the present Chief of the Bureau of Water, is approximately as follows:

Work finished or under contract	$26,000,000
Other work, estimated	2,250,000
Total	$28,250,000

This cost is divided approximately as follows:

Delaware River	$14,250,000
Schuylkill River	7,000,000
Distribution system	5,500,000
Repairs to pumping stations	1,500,000
Total	$28,250,000

CAPACITY.

The consumption, in 1907, as deduced from plunger displacement, was about 300,000,000 gallons per day. The works, when completed, will have a capacity of 340,000,000 gallons per day, probably rather less than the increased demand of that time. These 340,000,000 gallons would be ample for a population of five million persons, but they will prove a scant supply for our one and one-half millions, because our people prefer to be robbed by a small minority, which wastes far more that the decent majority uses.

COMPLETION.

The Roxborough works, supplying 25,000,000 gallons daily, have been furnishing filtered water since 1903; and the Belmont works, 40,000,000 gallons* daily, since 1904. The Torresdale works are now supplying about 110,000,000 gallons daily to the northeastern portion of the city. The central portion of the city, still supplied with raw water, may be said to be bounded by the

*With scrubbers, 50 million.

two rivers, by Spring Garden Street, east of Broad Street, and by Allegheny Avenue west of Broad Street.

It is expected that the Torresdale works will be finished during the current year, and the Lardner's Point plant in 1909, or about ten years after the inauguration of Mayor Ashbridge. The work for Queen Lane reservoir is not yet under contract, and no time is set for its completion.

For information respecting changes made since my resignation from the Water Bureau in 1899, I am indebted principally to the present Chief of the Bureau, Mr. Fred. C. Dunlap.

THE BORAX INDUSTRY IN 1906.

The entire output of borax in the United States is derived from San Bernardino, Inyo, and Ventura counties, California, and up to and including 1906 the greater part of it has come from San Bernardino County.

Until 1903, the annual statistics of production collected by the United States Geological Survey were based on the quantity and value of the refined product, but since then crude borax has been taken as a basis, as the prepared borax is essentially a manufactured product. The quantity of crude materials mined (borate of lime or colemanite), with varying richness of boric acid, is readily ascertained, and the value of the crude material is therefore calculated according to the percentage of boric acid it contains.

The total output of crude borax for the year 1906 was 58,173 short tons, valued at $1,182,410, as against 46,334 short tons, valued at $1,019,154, in 1905, an increase in 1906 of 11,839 short tons in quantity and of $163,256 in value. The imports of borax, boric acid, and borates into this country in 1906 were valued at $62,979, an increase of $20,179 over the value of the imports for 1905, which amounted to $32,800.

The cost of crude borax varies materially with different producers, owing to local conditions, length of haul to railroad, etc. Some of it is also semi-refined before shipment and subsequently fully refined at points far distant from those of production.

Statistics of the production of borax in the United States in 1906, prepared by Charles G. Yale, are published by the United States Geological Survey in an advance chapter from "Mineral Resources of the United States, Calendar Year 1906," which is now ready for distribution.

Notes On Theory and Practice of Evaporation.

By Philip B. Sadtler, S.B.

(*Continued from vol. clxvi, p. 296.*)

PRACTICAL CONSIDERATIONS IN THE DESIGNS OF EVAPORATORS.

Data Necessary for Designing:—The successful designing of an evaporator is dependent first on the recognition of certain chemical and physical facts relating to the substance to be evaporated; second, on whether or not due regard is paid to certain thermal and thermo-dynamic principles involved, and third, on certain mechanical features that arise in the construction. It is not to be supposed that either an engineer, familiar with the best boiler practice, or a chemist, familiar with laboratory or open pan evaporation in the works, could successfully design a Multiple Effect Evaporator. But certain facts in regard to design should certainly aid either a chemist or engineer in procuring the proper design or making a purchase.

As the principal purpose of an evaporator is to concentrate a solution of some sort, it will be readily seen that the chemical and physical laws governing concentrated solutions will be of importance. These are only known qualitatively and the quantitative laws which govern the chemistry of dilute solutions are inapplicable.

As most measurements of the concentration of solutions in the works are made with a hydrometer we generally speak of concentrating between certain limits in degrees, Beaumé, Twaddell, Brix, Salinometer, or Specific Gravity. It is, therefore, necessary to obtain or devise tables or curves showing the relation of these units of concentration with the percentage of solid matter in solution. The purpose of this is to obtain accurate information as to the actual amount of water that is going to be evaporated in a unit of time. This is especially important in cases where the

vapor arising from the solution is the source of heat in the succeeding effect of the evaporator.

Of equal, or greater importance, is a table or curve for a given solution which shall accurately show the relation between the boiling point of the solution and its concentration. It will be shown below, that the boiling point of a solution at any period of its progress through the evaporator has a direct bearing upon the size of the evaporator. A boiling point curve is generally obtained by taking simultaneous readings upon a hydrometer and thermometer, while boiling a solution actively under atmospheric conditions. This may best be accomplished in a laboratory where accurate means of determination are provided. After this curve is obtained a correction should be made for temperature at boiling to bring the hydrometer readings to the same temperature standard.

In cases where a substance is intended to precipitate from solution, during the process of evaporation, there should be used in conjunction with the above table also a table of solubilities of the substance at different temperatures.

The thermodynamic data necessary consist of the regular steam engineer's tables, showing the relations between temperature, pressure, heat of liquid, heat of vaporization, etc.

There are other chemical and physical data of which account must be taken in designing. The more information obtainable in regard to possible incrustation and scaling of heating surface, the clearer will be the idea as to what mechanical features to introduce for the removal of scale and as to what excess capacity to allow for this contingency. As in boiler practice, one of the greatest sources of annoyance is the deposition of gypsum on the tubes. This annoyance is encountered in the salt industry especially; due to the peculiar solubility relation of gypsum, it is found more expedient to evaporate at low temperature with large heating surface, thus minimizing the scale. Another similar case is that of soda washings in pulp mills, where cooking liquor is evaporated for soda recovery. If the lime used in the course of the process is high in silica and alumina, these find their way to the evaporator and deposit in a dense fibrous scale. If such possibilities as these are to arise, it is found expedient to have the heating surface in excess of the calculated area and easily removable from the evaporator for cleaning purposes. Moreover, it should be removable

where corrosion is expected. There are some chemical solutions which corrode iron, at the higher temperatures but are inactive at lower temperatures. In these cases the heating surface bears the brunt of the destruction in the evaporator.

Another important question is, as to the nature of a solution's activity under boiling conditions. In other words, does the boiling solution tend towards entrainment or foaming, or spattering. These points must be known beforehand, as they decidedly influence the proportioning of the evaporator. Figure 3 shows a

Fig. 3

large cylinder, known as a *catch-all*, placed above the vapor dome, in order to catch entrained sugar solution carried along with the vapor by the force of the ebullition in the evaporator. The sectional area of this cylinder, being greater than that of the vapor pipes leading off from the evaporator, there is caused a diminution of the rate of flow of steam and a consequent dropping out of the entrainment.

Figure 4 shows an evaporator built to evaporate pulp mill wash

waters containing large amounts of resinate of soda. This is very foamy when in process of ebullition. In designing this apparatus it was found best to build the tubes up in four banks, so that the upper part of the heating surface would kill the foam. Thus, when the apparatus is in operation the liquid level is rather low and the two upper banks heat the foam arising from the lower part and cause it to subside.

Figures 5, 6 and 7 show different views of an evaporator used on sugar and glucose, having two banks of tubes. The floor

Fig. 4

under the upper bank "B" acts as a baffle to decrease the entrainment from the lower bank "B;" the vapor arises from the lower level "K" and passes through the side vapor pipes "CC" into the vapor space. By this method the entrainment is decreased and the apparatus has a larger evaporative capacity for its size.

Calculation of Heating Surface:—The amount of heating surface necessary, depends primarily on the amount of water to be evaporated, the number of effects desired, the initial steam pressure, the boiling points of the solution to be evaporated, and the

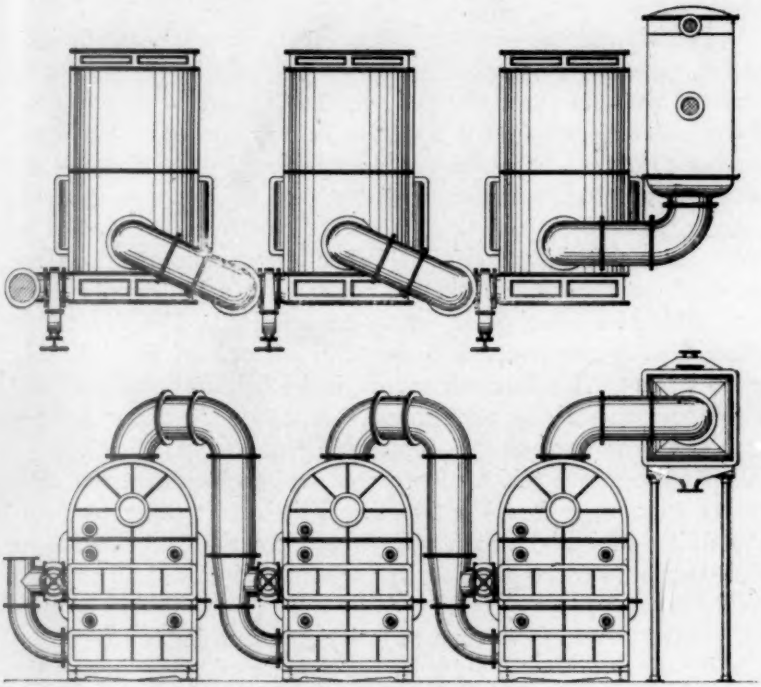

Fig. 5

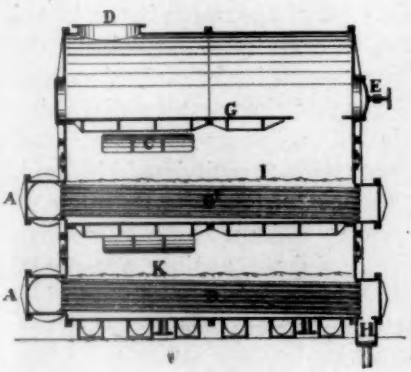

Fig. 6

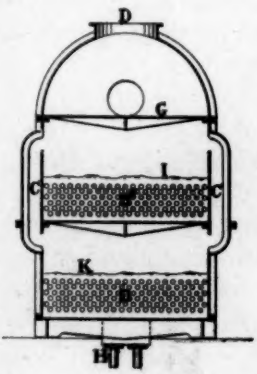

Fig. 7

evaporative factor for a given type of machine, and for a given solution to be evaporated.

In calculating the amount of water to be evaporated, it is merely necessary to obtain from tables or analysis, the percent of solids in the dilute and the concentrated liquor. From this we can obtain the amount of water to be evaporated. When the number of effects, in which the evaporation is to be done, is determined, a calculation should be made of the water evaporated in each effect and from that, what the concentration should be maintained at, in each effect. When these concentrations are known the corresponding boiling points should be found from a good table of boiling points or by experiment. The *degrees* of *excess boiling* temperature is the total of each of these boiling points less 212°F. In other words, if the boiling points in three effects are respectively 214°, 220°, and 236°, the excess boiling temperature is $(214\text{-}212)+(220\text{-}212)+(236\text{-}212)=34°$.

From the steam tables of pressure and temperature the *total temperature range* should be found. This is the temperature corresponding to initial steam pressure minus the temperature of steam pressure corresponding to vacuum maintained in the last effect.

The evaporative factor is a quantity constant derived from ex- *effective range*. This divided by the number of effects equals the *average effect difference*.

The evaporator factor is a quantity constant derived from experience and operative tests on the type of apparatus best adapted and on the given class of liquor to be evaporated. Probably the same factor would hold, for instance, on all horizontal submerged tube evaporators of the general type of those under discussion and would hold for either caustic soda solutions or carbonate of soda solutions. In fact the same constant quantity could be used, and has been used, in designing evaporators for a large range of inorganic chemical solutions, such as sodium chloride, sodium hydrate, sodium carbonate, sodium sulphate, sodium phosphate, sodium acid phosphate, sodium thiosulphate, potassium chloride, potassium hydrate, ferrous sulphate, calcium acetate, etc., etc. However, in cases of tannic acid, sugar, glucose, glycerine, black liquor, or resinate of soda, packing house tankage, garbage tankage, etc, somewhat different conditions obtain and the factor varies. The factor also differs slightly for different materials for

the heating surface. That for copper or aluminum being distinctly higher than that for iron.

To specify the units on which this factor is generally based we might say that it is expressed as gallons of water evaporated, per square foot of heating surface per degree difference in temperature per hour.

If C = evaporative factor
E = average effect difference
W = gallons evaporated
T = time in hours during which evaporation proceeds
S = square feet of heating surface

$$C = \frac{W}{E \times T \times S}$$

Hence, if we find from experience or trial tests the value of C and if we calculate E and W, as explained above, it is easy to obtain the required heating surface.

(To be continued.)

GOLD AND SILVER OUTPUT OF COLORADO IN 1906.

Statistics collected by the United States Geological Survey show that Colorado still outranks any other State or Territory in the Union, including Alaska, in the production of the precious metals, despite the fact that the gold production of the State in 1906 fell short nearly $2,000,000 of that of 1905, the precise figures being, output $23,210,629, decrease $1,813,344.

More than half of the total gold of the State is derived from the telluride veins of Cripple Creek in Teller County. San Miguel free-milling ores contribute nearly $2,500,000. The smelting ores of Leadville, in Lake County, yielded $1,500,000 and the partly free-milling Gilpin County ores over $1,000,000. San Juan County and Ouray County both closely approached the million-dollar mark. Important diminution in the output is recorded in Teller and Ouray Counties, but this was partly offset by gains in San Miguel and other counties. Siliceous and dry ores formed 67 per cent. of the total tonnage and were the source of over 96 per cent. of the gold product. The placer output is comparatively small. The outlook for 1907 does not indicate the probability of great increase, if any.

The production of silver, 12,216,830 ounces, showed an increase of 717,523 ounces. The smelting ores of Lake County led in the output, with nearly 4,000,000 ounces, while in their order Pitkin, San Miguel, Mineral, San Juan, Ouray, and Clear Creek Counties are next in importance, the first three exceeding the million mark. A higher price increased the value of the product. The increase is due chiefly to the veins of San Juan, San Miguel,

and Mineral Counties. On the other hand, the yield of the Leadville and Aspen deposits diminished.

About half of the silver product of the State is derived from silicious or dry ores, 28 per cent. from lead ores, and 17 per cent. from zinc or zinc-lead ores. No great change is expected in the production of silver for 1907.

The Geological Survey published during December an advance chapter from "Mineral Resources of the United States, Calendar Year 1906," containing a discussion by Waldemar Lindgren, geologist, of the gold and silver production of the United States in 1906.

DOMESTIC PRODUCTION OF BISMUTH.

The United States has been but a small producer of bismuth ores, and these have been shipped abroad for refining. Meanwhile this country has imported refined bismuth to a much greater value than that of its exports of the raw material.

The only bismuth produced in the United States in 1906, so far as reported, was derived from two mines at Leadville, Col., whose output was 8334 pounds, valued at $12,500. The imports of bismuth during the year amounted to 254,733 pounds, valued at $318,452, but no record was kept of the importation of bismuth compounds.

Bismuth ores are known to occur at a number of other localities in Colorado besides Leadville; in southeastern New Mexico; in southern California; on Charley Creek, 35 miles north of Nome, Alaska; at Hailey, Idaho; on Reese River, Nevada; and west of Salt Lake, Utah; but production was not reported from any of these deposits in 1906.

The refining of bismuth does not appear to be difficult, but the large smelting companies do not care to undertake so small a business, while the smaller firms apparently do not wish to antagonize the foreign firms, who now control the trade. Some lead ores carry bismuth, and when lead is refined electrolytically the bismuth remains in the residual mud. It is thought that the lead refineries using this process may turn out some bismuth in the future.

By far the largest producer of bismuth is Bolivia, whose exports for 1906 amounted to $722,978. Other countries that are either actual or potential producers of the material are Bohemia, Mexico, New South Wales, Norway, Spain, and Tasmania.

The wholesale price during 1906 was much lower than has often prevailed, ranging around $1.25 per pound. This condition was generally attributed to the desire of the controlling firms to crush out competition, a new refinery having been started in Germany.

Bismuth is used chiefly in pharmaceutical preparations, such as the subnitrate, the combinations with the haloids, and the tennate. It is also used in low-fusing alloys or cliché metal, and to a small extent in glass.

The condition of this industry in 1906 is reported by Frank L. Hess, geologist, of the United States Geological Survey, in an advance chapter from "Mineral Recources of the United States, Calendar Year 1906," which is now ready for distribution by the Survey.

Alumni Association of the Franklin Institute.

On Monday evening, April 27th, 1908, about seventeen graduates of the schools of the Institute assembled in the Hall for the purpose of forming an Alumni Association.

Mr. Walton Clark, President of the Institute, presided, and assured the meeting of his approval of its object and his hearty cöoperation and that of the Board of Managers and prophesied an interesting and important future for the Association.

Mr. William H. Thorne, the Director of the Drawing School, spoke of the value of such an association, both to the graduates and to the Institute, and hoped that great care would be exercised at the beginning in the forming of the Constitution and By-Laws and the selection of the officers, in order that permanency and success might be assured.

Mr. George S. Cullen, an old graduate and instructor, discussed eligibility for membership. Enthusiastic approval of the object was shown by the remarks of Messrs. Pedrick, Jones, Parsons, McCaffrey, Delaney, Fisher, Fennell and Davis, and Dr. Wm. H. Wahl, Secretary, and Mr. Henry Howson, Vice-President of the Institute.

On motion of Mr. Delaney, it was unanimously resolved that "It is the sentiment of this meeting that an association of the students of the Franklin Institute be formed and that the graduate students attendant at this meeting constitute themselves the charter members of such association."

On Motion of Mr. Fennell, it was resolved that "A committee on Constitution and By-Laws be appointed by the President of the Institute, to consist of five members, and that Mr. Thorne be appointed chairman."

On motion of Mr. Fennell it was resolved that "A committee of five be appointed by the President of the Institute to nominate permanent officers of the association."

The President appointed the following as the Committee on Constitution and By-Laws: Messrs. Thorne, Parsons, Cullen, Jones and McCaffrey.

On motion adjourned.

WM. H. THORNE, *Secretary.*

A meeting for the purpose of considering the reports of the Committee on Constitution and the Committee to nominate permanent officers was held on the evening of October 12th, 1908, in the Hall of the Institute. Mr. William H. Thorne, Director of the Drawing School, called the meeting to order. In the absence of Mr. Walton Clark, President of the Institute, Mr. Clement Remington was made temporary chairman. The following constitution was considered and discussed section by section and finally adopted:

CONSTITUTION OF THE ALUMNI ASSOCIATION OF THE FRANKLIN INSTITUTE.

ARTICLE I.

Name.

SECTION 1. The name of this organization shall be THE ALUMNI ASSOCIATION OF THE FRANKLIN INSTITUTE.

ARTICLE II.

Object.

SECTION 1. The object of this Association shall be to promote the interests of the Institute and of its schools and of the alumni.

ARTICLE III.

Membership.

SECTION 1. The Association shall consist of Members, Life Members, and Honorary Members.

SEC. 2. Every graduate of the Franklin Institute schools, by virtue of his or her diploma, may become, upon application to the Membership Committee, a member of this Association, and shall be entitled to all the rights of membership as long as he or she complies with the regulations of the Constitution. Provided, no one shall be entitled to hold office or to vote unless he has paid all dues in full to date. Former pupils of the schools not having received diplomas, may become members upon application, if recommended by the Membership Committee, and elected by a two-thirds vote of the members in attendance at any stated meeting.

SEC. 3. Any member in good standing may become a Life member of the Association by the payment of $20.00 at one time, and shall thereafter be exempt from the annual assessment levied to meet the ordinary expenses of the Association, for which purpose the income only of Life membership money shall be used, the principal to be invested. In all other respects,

the status of the Life member shall be the same as that of the regular members.

SEC. 4. Honorary members may be chosen from among any individuals who have been of great service to the Institute. They must be nominated by a member in good standing and recommended by the Membership Committee and elected by a two-thirds vote of the members in attendance at any stated meeting. An interval of a year shall elapse between the proposal and election of an Honorary member.

SEC. 5. The Membership Committee shall consist of six, two members of which shall be appointed annually for a term of three years by the President, who shall be chairman of such Membership Committee. The first President of the Association shall appoint the first Membership Committee, and two of the six so appointed shall retire by lot at the expiration of each of the two years next succeeding.

ARTICLE IV.

Dues.

SECTION 1. Each member shall pay on admission a fee of 50 cents, which fee, with the Life Membership fees, shall be put at interest and the income only used.

SEC. 2. Each member shall pay annual dues of $1.00 to the Treasurer on or before the first Monday in May of each year. Any member in arrears for dues for two years shall be notified by the Treasurer, and if such arrears are not paid within thirty days after such notice, then the member so in arrears may, at the option of the Executive Committee be dropped from membership of the Association. The Executive Committee shall have power to restore to membership any former member so dropped from membership, who shall make application for such restoration, and pay to the Treasurer the dues for each year since his last payment.

ARTICLE V.

Officers.

SECTION 1. The officers shall consist of a President, a First Vice-President and a Second Vice-President, a Secretary, a Treasurer, an Archivist and an Executive Committee, which committee shall consist of the President and Secretary and eight other members elected for a term of four years, two being elected each year, except that eight members shall be elected at the first meeting of the Association and these eight members shall determine their respective terms of office, four, three, two or one year, by lot. All the officers except the Executive Committee shall be elected for a term of one year, and the President shall not be eligible for consecutive re-election.

SEC. 2. The Executive Committee shall appoint at each stated meeting of the Association, a Nominating Committee of seven members, which committee shall present to the next stated October meeting, nominations for the several officers named in the preceding section. The meeting shall thereupon proceed to an election. The election of officers shall be by ballot, and

the officers so elected shall take office upon the adjournment of the meeting at which they are elected.

SEC. 3. Twenty or more members entitled to vote, may constitute themselves a special nominating committee with same powers and limitations as the nominating committee appointed by the Executive Committee.

SEC. 4. It shall be the duty of the President to preside at all meetings of the Association; to preserve order, and to vote in the case of ties only.

SEC. 5. In the absence of the President, the senior Vice-President present shall perform the duties of the President.

SEC. 6. The duties of the Secretary shall be to record the action of meetings; to keep a correct list of all members; to give timely notice of all special and stated meetings; to receive and answer all corrspondence of the Association and to lay the same before the next stated meeting; to preserve correct copies of the minutes, to deliver to the Archivist all addresses, essays, and correspondence, and to notify the new members and officers-elect of their election and members of Committees of their appointment.

SEC. 7. It shall be the duty of the Treasurer to collect all fees; take charge of all funds of the Association; pay all bills approved by the Executive Committee and endorsed by the President, and at each regular meeting to present a written statement of the finances. His accounts shall be audited annually by a committee of three appointed by the President at each May meeting. This committee shall report to the next stated October meeting.

SEC. 8. It shall be the duty of the Archivist to have charge of the archives belonging to the Association. He shall be the custodian of all addresses and essays of members, of all drawings, sketches, paintings, models or productions of the schools and alumni which may be donated, and of all trophies and insignia belonging the the Association. He shall arrange in files all correspondence of the Association, all receipted bills, and such other memoranda as may be deposited with him by the Executive Committee. He shall have charge of the rooms and furniture of the Association and be responsible for the display and care of attractive or valuable archives, subject to the regulations of the Board of Managers of the Institute. He shall reside within twenty miles of the Franklin Institute Building.

SEC. 9. It shall be the duty of the Executive Committee to make the necessary arrangements for the meetings of the Association; to obtain suitable persons to read essays to the Association; to examine each bill presented for payment and to approve or reject the same, to attend to all business not otherwise provided for, and to act when so requested in an advisory capacity to the Directors of the Schools. It shall make a full report of its actions to each stated meeting.

ARTICLE VI.

Meetings.

SECTION 1. There shall be two stated meetings annually, viz.,—on the first Monday in May and on the first Monday in October. Other meetings shall be held as may be provided by the By-Laws.

SEC. 2. Special meetings may be called by the President, and must be called by the President upon the written request of twenty members of the Association.

ARTICLE VII.

Amendments.

SECTION 1. This Constitution may be added to, or amended, at any regular or special meeting upon a two-thirds vote of the members of the Association present. Provided, the proposed amendment shall have been presented to the Secretary over the signature of not less than twenty members, and a copy mailed by him, together with the notice of the meeting, to each member of the Association, not less than fourteen days prior to such meeting. It shall be the duty of the Secretary to mail each member a copy of any properly proposed amendment as above.

The Nominating Committee presented the following candidates for the various offices and they were unanimously elected:

President, George S. Cullen.
First Vice-President, Percy Stokes.
Second Vice-President, Edward T. Parsons.
Secretary, Thomas G. Jones.
Treasurer, Edward V. McCaffrey.
Archivist, Lucien E. Picolet.

Executive Committee:—
Louis Laherrere.
Howard G. Balz.
Anders Forsstrand.
R. S. Garren.
Frank H. Lobb.
Clarence C. Fithian.
E. Winfield Finkbiner.
Oscar Mowrey.

The following persons have complied with Article 4, Section 1, of the Constitution and thereby become members of the Association.

J. T. Fennell, 311 Walnut St.
John H. Wackenhut, 2104 Montgomery Ave.
Wm. B. Champion, Haddon Heights, N. J.
Thomas J. Delaney, 2463 N. 31st St.
L. Laherrere, 1822 Mt. Vernon St.
R. S. Garren, 1318 Spruce St.
Edw. C. Pladder, 513 Perth St.
J. E. Schultzer, 223 N. 7th St., Chester, Pa.
Frank H. Lobb, 432 Carteret St., Camden, N. J

Theo. H. Glockner, 29 E. Sevmour St., Germantown.
Warren M. Stone, 113 Linden St., Camden, N. J.
Edw. F. Parsons, 19 N. 24th St., Camden, N. J.
John McCoy, 57 E. Mermaid Lane.
Jas. R. McCausland, 1831 N. 19th St.
Fred. W. G. Haussman, 328 Brown St.
Thos. J. McLoughry, 2009 Norris St.
Chas. Seifert, 2344 N. 25th St.
George Todd, 532 E. Cabot St.
Chas. F. Huegle, 1239 N. 5th St.
Valentine J. Huegle, 1239 N. 5th St.
Alvin B. Hatfield, 2612 Glenwood Ave.
E. Fisher, 926 N. 4th St.
Gomer Hogstrom, P. O. Box 201, Riverside, N. J.
Anders Forsstrand, 2104 Ontario St.
Alex. Arnois, 1304 Arrott St., Frankford.
W. A. McCaffrey, 1711 N. 4th St.
John F. Abbott, 5107 Hazel Ave.
Oscar Mowrey, 1647 Newkirk St.
Malcolm Lovett, 5022 Market St.
Clarence C. Fithian, 1109 Wallace St.
Louise Fithian, 1109 Wallace St.
Herman J. Ruch, 172 Woodland Ave., Woodbury, N. J.
E. W. Finkbiner, 5218 Stiles St.
Jas. C. Wobensmith, 1011 Chestnut St.
Harry Harres, 1017 Lombard St.
Percy Stokes, 1822 N. 16th St.
Thos. G. Jones, 2063 E. York St.
Geo. S. Cullen, 4504 Springfield Ave.
E. V. McCaffrey, 1711 N. 4th St. (Life Member.)

THOMAS G. JONES, *Secretary.*

Book Notices.

Steam., Its Profitable Utilization. By Geo. H. Gibson. 12 pages 6¾x10 in., illustrated. Reprinted from The Book-keeper by the Harrison Safety Boiler Works, Philadelphia, Pa. For gratis distribution to managers and others who are responsible for the economical performance of steam plants.

While presumably written with a view to exploiting the products of the above named firm, this pamphet describes in considerable detail the requirements of various prime movers, tracing out the distribution of heat in the various parts of the system and pointing out when economies may be effected and the means by which they may be carried out.

One conclusion reached is the greater economy resulting from a utilization of exhaust steam than from the installation of elaborate power producing apparatus of high efficiency. P.